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Inorganic Arsenic Emissions from Glass Manufacturing Plants Background Information for Proposed Standards

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Inorganic Arsenic Emissions from Glass Manufacturing Plants - Background Information for Proposed Standards

A national emission standard for glass manufacturing plants is being proposed under authority of Section 112 of the Clean Air Act. The purpose of the proposed standard is to minimize glass manufacturing furnace arsenic emissions to the level which, in the judgment of the Administrator of the U. S. Environmental Protection Agency, provides an ample margin of safety to protect the public health. The standard will have the effect of reducing uncontrolled emissions of arsenic from these furnaces by about 90 percent. Environmental impact and economic impact statements quantifying the impacts of the proposed standard and alternative control options are included in the document.

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Inorganic Arsenic Emissions from Glass Manufacturing Plants - Background Information for Proposed Standards

Emission Standards and Engineering Division

U.S ENVIRONMENTAL PROTECTION AGENCY
Office of Air, Noise, and Radiation
Office of Air Quality Planning and Standards
Research Triangle Park, North Carolina 27711

April 1983

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ENVIRONMENTAL PROTECTION AGENCY

Background Information
and Draft Environmental Impact Statement
for Inorganic Arsenic Emissions from
Glass Manufacturing Plants

Prepared by:

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(Date)

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1. The proposed standards of performance would limit emissions of inorganic arsenic from existing and new glass manufacturing plants. The proposed standards implement Section 112 of the Clean Air Act and are based on the Administrator's determination of June 5, 1980, (44 FR 37886) that inorganic arsenic presents a significant risk to human health as a result of air emissions from one or more stationary source categories, and is therefore a hazardous air pollutant. States within the Northeast United States would be particularly affected.

2. Copies of this document have been sent to the following Federal Departments: Labor, Health and Human Services, Defense, Transportation, Agriculture, Commerce, Interior, and Energy; the National Science Foundation; the Council on Environmental Quality; members of the State and Territorial Air Pollution Program Administrators; the Association of Local Air Pollution Control Officials; EPA Regional Administrators; and other interested parties.

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1.0 SUMMARY

1.1 REGULATORY ALTERNATIVES

National emissions standards for hazardous air pollutants (NESHAP) for control of inorganic arsenic emissions from glass manufacturing plants are being developed under the authority of Section 112 of the Clean Air Act. These standards would affect furnaces in the glass industry that melt arsenic containing glasses.

Three regulatory alternatives were considered. Regulatory Alternative 1 is the baseline alternative and represents the level of control that would exist in the absence of any NESHAP regulations. Regulatory Alternative 2 represents the control level achievable by a fabric filter or an electrostatic precipitator. Regulatory Alternative 3 is the most restrictive and would require zero emissions, that is complete elimination of the use of arsenic in glass manufacturing.

1.2 ENVIRONMENTAL IMPACT

Although emissions data are not available for all arsenic emitting furnaces in the glass manufacturing industry, available data indicate that current annual arsenic emissions are at least about 37 Mg. This is the emissions level that would exist under Regulatory Alternative 1. The emissions level under Regulatory Alternatives 2 and 3 would be 4.3 Mg/year and zero, respectively. This represents an industry-wide 88 percent reduction for Alternative 2 and 100 percent reduction for Alternative 3.

There would not be any water pollution impact under any of the regulatory alternatives. There will be a relatively small negative solid waste impact under Regulatory Alternative 2. There will be a relatively small increase in energy use under Regulatory Alternative 2 and a small energy savings under Regulatory Alternative 3. A summary of the environmental and energy impacts associated with the three regulatory alternatives is shown in Table 1-1.

TABLE 1-1. ENVIRONMENTAL AND ECONOMIC IMPACTS OF REGULATORY ALTERNATIVES

Administrative Action	Air Impact	Water Impact	Solid Waste Impact	Energy Impact	Noise Impact	Economic Impact
Regulatory Alternative I (No Action)	0	0	0	0	0	0
Regulatory Alternative II	+4**	0	-1**	-1**	-1**	-1**
Regulatory Alternative III	+4**	0	+1**	+1**	0	-4**

KEY:
+ Beneficial impact
- Adverse impact
0 No impact
1 Negligible impact
2 Small impact
3 Moderate impact
4 Large impact
* Short-term impact
** Long-term impact
*** Irreversible impact

1.3 ECONOMIC IMPACT

Regulatory Alternative 2 is expected to result in a total industry capital cost of about 30 million dollars and an annualized cost of about 5.4 million dollars. There would be no capital or annualized control costs associated with Regulatory Alternative 3. However, there will be a negative economic impact under this alternative due to elimination of the production of arsenic-containing glasses and possibly the shut down of glass melting furnaces that produce arsenic-containing glasses. A detailed cost analysis is presented in Chapter 6 of this document. An economic analysis is presented in Chapter 7. Table 1-1 shows the economic impacts associated with the three regulatory alternatives.

2.0 THE GLASS MANUFACTURING INDUSTRY

This chapter presents general information on the glass manufacturing industry including a description of the glass producing processes and a discussion of atmospheric emissions.

2.1 INDUSTRY DESCRIPTION

The glass manufacturing industry is classified in accordance with the industry definitions embodied in the Standard Industrial Classification (SIC) system. Under this system of classification, an industry is generally defined as a group of establishments producing a single product or a more or less closely related group of products. Accordingly, for the glass industry there are four SIC codes:

SIC 3211 - Flat glass
SIC 3221 - Container glass
SIC 3229 - Pressed and blown glass, not elsewhere classified (N.E.C.)
SIC 3296 - Wool fiberglass

The products produced by the glass industry are extremely diverse in nature. Although the major basic manufacturing operations are common in the various industry segments, the chemical composition and corresponding properties of the products may vary significantly between products of the various segments as well as between different products produced within a given segment. The use of arsenic in the glass industry is mainly concentrated in the manufacture of certain products in the pressed and blown, n.e.c. segment. The flat glass and container glass segments have used arsenic in the past but are now reported to have virtually eliminated the use of the substance. There has not been any known use of arsenic in the wool fiberglass segment. The following description of the various glass industry segments, therefore, concentrates on the pressed and blown sector.

2.1.1 Flat Glass Industry[1]

This industry contains establishments primarily engaged in manufacturing flat glass as well as some laminated and tempered glass. Almost 100 percent of the flat glass produced is soda/lime glass. The basic ingredients of soda/lime flat glass are sand (SiO_2), soda ash (Na_2CO_3), and limestone ($CaCO_3$ plus some $MgCO_3$). Typical composition of soda/lime flat glass is as follows:

SiO_2	71 to 74%
Al_2O_3	0 to 2%
Na_2O	12 to 15%
CaO	8 to 12%

The major products shipped by the flat glass industry are window glass, plate and float glass, rolled and wire glass, tempered glass, and laminated glass.

Four flat glass products -- float, sheet, rolled, and plate -- are manufactured in the United States. Of these, float glass accounts for more than 90 percent of the total flat glass production. Float glass is made by floating molten glass from the melting furnace on a bath of molten tin until the glass hardens. This glass, with its high optical quality, has replaced plate glass, which required grinding and polishing to produce a smooth surface. It is used for automobile windows and large picture windows. Average thickness ranges from 3.2 to 6.4 mm. Sheet glass is made by drawing molten glass upward from the melt. It is thinner than float glass (1.6 to 3.2 mm) and is used for windows in residential construction. Rolled or patterned glass is formed by drawing molten glass through rollers with patterns impressed on them. This decorative glass is used for special purposes such as shower doors and partitions. Plate glass is made by drawing molten glass through smooth rollers and then grinding and polishing both glass surfaces to a smooth finish.

The use of arsenic in the flat glass segment is reported to have been eliminated in the past few years. Arsenic can potentially add some desirable properties to some specialty flat glass products such as chemically strengthenable flat glass used in aircraft and spacecraft windows[2] and solar collectors.[3] However, there are no flat glass plants currently known to be using arsenic.

2.1.2 Container Glass Industry[4]

Glass containers (SIC-3221) is the largest of the three major segments of the glass industry. It includes the manufacture of narrow-neck and wide-mouth glass containers for foods, beverages, medicines, toiletries, and cosmetics. Three general types of container glass are produced: amber, green, and clear.

Soda/lime is the major type of glass produced in the container glass segment. The basic raw materials for soda/lime container glass are silica sand, soda ash (Na_3CO_3), and limestone (primarily $CaCO_3$, plus some $MgCO_3$ in dolomitic limestones). Feldspathic minerals (anhydrous aluminosilicates containing potassium, sodium, and calcium in varying ratios) are also utilized as sources of alumina and alkali. Minor amounts of other oxides exist as impurities, and additional minor ingredients are added for specific purposes. A typical soda/lime glass-batch composition is:

Silica sand	55%
Soda ash	19%
Feldspar	7%
Limestone	18%
Salt cake (Na_2SO_4)	0.5%

According to industry sources, the use of arsenic in the container glass industry has been virtually eliminated. However, there is at least one specialty container glass plants in the United States that is known currently to use arsenic.

2.1.3 Pressed and Blown (N.E.C.) Industry[5]

The pressed and blown glassware industry, as represented by SIC-3229, essentially includes all industrial establishments primarily engaged in manufacturing glass and glassware that is pressed, blown, or shaped from glass produced in the same establishment. It consists of every category of glass or glassware except flat glass (SIC-3211), glass containers (SIC-3221) and wool fiberglass (SIC-3296). Establishments include those manufacturing textile glass fibers; lighting, electronic, and technical ware; and machine-made and handmade table, kitchen, and art-ware glass products. By far, the major use of arsenic in the glass industry is in the pressed and blown glass segment. Compositionally, the four important categories of glass manufactured by the pressed and blown glass industry are as follows:

Glass category	Estimated percent of total production
Soda/lime	77
Borosilicate	11
Lead silicate	5
Opal	7

Soda/lime glasses are overwhelmingly the most important type of glass in terms of variety of use as well as in tonnage melted. The combination of silica sand, soda ash, and limestone produces a glass that is easily melted and shaped and that has good chemical durability. Primary pressed and blown products employing this type of glass are incandescent lamps, tubing, and tableware.

Borosilicate glasses are basically a combination of silica sand, boric oxide, and soda ash. The borosilicate glasses have excellent chemical durability and electrical properties, and their low thermal expansion yields a product with high resistance to thermal shock. These combined properties make them ideal for demanding industrial and domestic uses such as chemical laboratory ware, cookware, pharmaceutical ware, and some lens reflectors and lamp envelopes. Pyrex^R, produced by Corning Glass Works, and Kimax^R, produced by the Kimble Division of Owens-Illinois, Inc., are examples of products made from borosilicate glasses.

Lead silicate glasses are composed of silica, lead oxide, and significant amounts of alkali oxide. The lead glasses are characterized by high electrical resistivity, high refractive index, and slow rate of increase in viscosity with decreasing temperature. This viscosity characteristic makes them particularly well suited to hand fabrication. Lead glasses are used in high-quality art and tableware, for special electrical applications, optical glasses, fluorescent lamp envelopes, and X-ray, gamma-ray, and neutron radiation shielding windows.

Opal glasses are translucent and may be colored. Commercial products of opal glass include lighting globes, ointment jars, dinnerware, and wall paneling. The translucency or opacity of opal glasses is produced by multiple scattering of light inside the glass. This scattering is achieved by the precipitation of crystals (or an immiscible amorphous phase) with an index of refraction different from that of the base glass. Commercial opal glasses commonly employ fluorine additions to yield opacifying crystals of sodium or calcium fluoride.

2.1.4 Wool Fiberglass Industry[6]

Wool fiberglass, the product of SIC-3296 segment, is used primarily as building insulation, accoustical ceiling tiles, heating and cooling pipe and duct insulation, and in process equipment and appliance insulation. There are no known wool fiberglass plants that have used arsenic in the past or are using the substance currently.

2.2 USE OF ARSENIC IN GLASS MANUFACTURING

Available information indicates that at least 15 glass plants are currently using inorganic arsenic in glass products. Except for some specialty container glasses, all the arsenic containing glass products made by these plants are pressed and blown glass products. Table 2-1 lists the arsenic containing glass products made by the 15 plants.

TABLE 2-1. PRODUCTS MADE BY FURNACES THAT EMIT INORGANIC ARSENIC

PRIMARY PRODUCTS
TV Picture Tube Components
Glass Tubing
Tableware Glass
Specialty Container Glass
Heat Resistant Globes
Electric Light Covers
Lead Glasses
Optical Glasses
Lead Crystal Glass

In recent years, the use of arsenic in many glass products has been either completely eliminated or has been reduced to the minimum amount that is technically necessary. This was accomplished by isolated investigations by individual companies to replace arsenic with other substances.[7] Such substitution must practically be determined individually for each type of glass. These research efforts often exceed the means of small and medium size glass companies and companies producing many different types of glasses. Therefore, the development occurred in the portion of the glass industry which almost exclusively produces only one kind of glass, i.e., soda/lime glass produced by the flat glass and container glass segments. Substitution was possible for soda/lime glass and the use of arsenic in this large area of glass production was eliminated by most companies.

Although arsenic is still being used in some soda/lime glass products in the pressed and blown glass sector, the primary types of glass where arsenic is used are lead, opal, lead silicate, borosilicate and aluminosilicate-ceramic. Inorganic arsenic compounds are used in glass manufacturing for a combination of reasons depending on the particular glass being produced. In the majority of cases, arsenic compounds act as fining or clarification agents. During the melting of the glass batch raw materials, gaseous reaction products such as oxygen, nitrogen, and carbon dioxide are evolved and rise through the glass melt in the form of bubbles. These bubbles greatly reduce the overall quality of the glass. The addition of the inorganic arsenic material causes the bubbles to rise more rapidly to the melt surface and dissipate. It also appears that chemical reactions brought about by the use of the arsenic reduce the release of some bubbles caused by nitrogen and carbon dioxide.[8] Fining agents act in various ways. As a result of their ready conversion between various oxidation stages, they can both take up and release oxygen. Arsenic is added to the glass batch in the form of powdered arsenic trioxide (As_2O_3) or liquid arsenic acid (H_3AsO_4). As_2O_3 with its trivalent and pentavalent oxidation stages is one of the classical fining agents. The overall formula for this redox equilibrium is as follows:

$$As_2O_3 + O_2 \longrightarrow As_2O_5 \qquad \text{(Ref. 9)}$$

The initial formation of the pentavalent stage is necessary and is brought about by other oxidizing agents, e.g., nitrates. (The use of arsenic acid essentially changes the input form to the pentavalent stage.) This pentavalent stage spontaneously releases the oxygen again at elevated temperatures. As a result, the bubbles which form as a function of the batch reaction become enlarged and rise more rapidly to the surface.

A second function of arsenic in glass is to act as a decolorizing agent. The effectiveness of arsenic trioxide in this use is again based on the ease of interconversion of the various oxidation stages.[10] This interconversion helps establish a concentration of arsenic pentoxide under the equilibrium conditions of the melt. Arsenic pentoxide oxidizes divalent iron impurities in the melt (which impart a greenish color to the glass) to a trivalent iron, which results in a yellowish color glass. The simultaneous addition of other elements such as nickel oxide, cobalt oxide, and rare earth oxides provides balancing colors which produce a colorless finished glass.[11]

Inorganic arsenic is also used in some instances in special glass types to impart particular properties that are needed for the end use of the glass. For example, arsenic can provide stable fixation of certain colors for optical glass by stabilizing selenium, provide high glass permeability to infrared light for camera lenses, and provide a high degree of energy transmission for solar collector glass.[12]

With the advent of environmental and occupational health laws for inorganic arsenic in the late sixties and early seventies, glass companies began reducing arsenic usage and initiating research into arsenic substitutes. In 1968 approximately 3,900 Mg (4,300 tons) of arsenic (elemental) were used, while in 1981 total usage was estimated at 730 Mg (800 tons).[13,14] Five percent of the total arsenic consumed in the United States goes into glass production.[15] Several manufacturers of television picture tube funnel glass have totally eliminated inorganic arsenic compounds from the feed batch raw materials.[16,17] Another manufacturer reports that since 1978 arsenic usage was reduced 50 percent in a fluoride opal glass and 30 percent in a borosilicate glass.[18]

2.3 GLASS MANUFACTURING PROCESSES

Although there are numerous unit operations used in the manufacturing of glass, most key processing steps, which generate the largest amounts of atmospheric emissions, are common throughout the industry. In this subsection, the basic operations are identified and discussed briefly.

2.3.1 Basic Process

Glass is manufactured in a high temperature conversion of raw materials into a homogeneous melt capable of fabrication into useful articles. This process can be broken down into three sub-processes: raw material handling and mixing; melting; and forming and finishing. Figure 2-1 gives a typical flow diagram for the manufacture of soda-lime glass;[19] however, it has general application to other commercial glass formulations.

The production of an arsenic glass involves melting a uniform mixture of raw materials in a furnace to obtain a homogeneous mass. Typical materials include sand, limestone, soda ash, feldspar, sodium sulfate and nitrate, anhydrous borax, potassium carbonate, and arsenic trioxide or arsenic acid. Arsenic compounds may be introduced into the batch as either arsenic trioxide powder or liquid arsenic acid with no effect on the overall glass making process. Inorganic arsenic is also introduced into the batch feed as a constituent of the return cullet or scrap glass. The level of inorganic arsenic in the cullet is the same as the percent retained in the glass of the total batch fill.[20]

2.3.1.1 Raw Material Handling and Mixing. The raw materials are received in packages or in bulk and are unloaded by hand, vibrator-gravity, drag shovels, or vacuum systems. Cullet, crushed recycled glass, must be segregated and transferred to storage bins by various processes including the utilization of bucket elevators, belt conveyors, or screw conveyors. In addition to bulk raw materials, certain minor constituents are packaged and stored in their original containers until mixed with the batch.

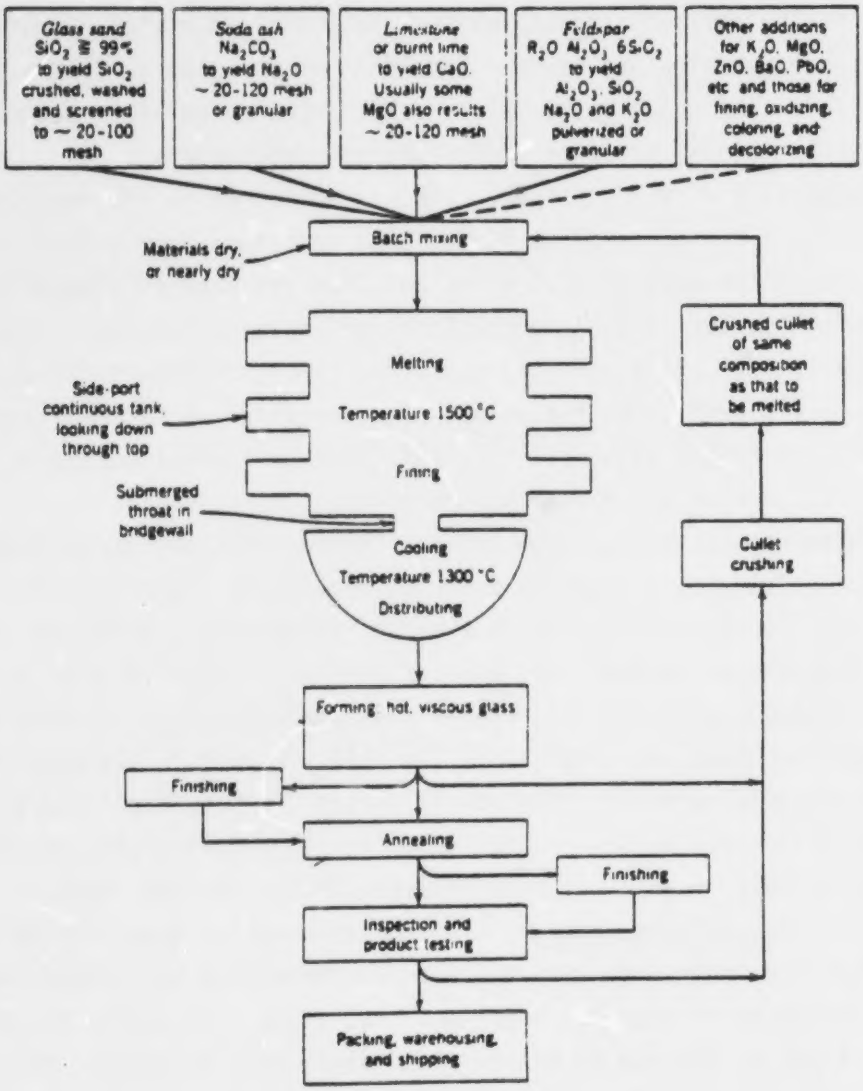


Figure 2-1. Process flow diagram.

Prior to being fed into the melting unit, the raw materials are mixed according to the desired product recipe. Weighing and mixing operations may be automated or carried out by hand depending on the size or specialty of the operation. The melters themselves are charged manually or automatically, usually through screw or reciprocating-type feeders.

A potential source of inorganic arsenic emissions in the raw materials handling part of the glass plant is fugitive emissions from arsenic trioxide handling. Fugitive arsenic dust emissions from raw materials handling are highly controlled due to OSHA regulations for airborne inorganic arsenic in the workplace. The glass industry uniformly controls these fugitive arsenic dust emissions by enclosing the unloading, conveying, and storage areas and venting them to fabric filters.[21,22] This type of control method is effective in lowering arsenic emissions to negligible levels.

The OSHA regulations are the primary reason that some glass companies have switched from using powdered arsenic trioxide to liquid arsenic acid. By using the liquid arsenic acid as a batch raw material, a minimal amount released into the workplace. One manufacturer has indicated that it now uses only liquid arsenic acid for their glass manufacturing in order to protect their workers and comply with the OSHA standard.[23] Because this source of potential arsenic emissions is already well controlled and the arsenic emissions are orders of magnitude less than controlled process arsenic emissions, it will not be discussed further in this chapter.

2.3.1.2 The Melting Process.[24] From the handling area, the weighed raw materials are delivered into the furnace where they are transformed through a sequence of chemical reactions into glass. In operation, the raw materials float on the bed of molten glass until they dissolve. Mixing in the molten glass bed is caused by gases evolved in chemical reactions and by natural convection currents in the molten glass bed. In addition, some furnaces have air injected in the bottom of the bed to augment ebullient mixing.

Within the temperature range of the furnace (1,500°C to 1,700°C), the glass exists as a liquid free of crystalline matter with a viscosity of 10 Newton-seconds per square meter ($N\text{-}s/m^2$) ($\sim$ 100 poise). Because the viscosity of the glass exiting the furnace must be compatible with the forming operations, the temperature of the molten bed is decreased gradually to a point until the viscosity of the glass is about 100 to 1,000 N-s/m^2 (10^3-10^4 poise). In addition to cooling as it flows through the furnace, the glass is retained in the furnace long enough for gaseous inclusions to be removed. From the introduction of raw materials to the extraction of a homogeneous melt suitably ready for forming, a furnace accomplishes three functions in glassmaking: to bring raw materials together to react; to hold the molten glass until it is free of bubbles and inclusions; and to condition the glass for forming.

Energy required for melting glass is supplied by burning either natural gas or fuel oil and sometimes by augmenting the energy produced from these fossil fuels with electricity which is converted to heat within the liquid glass bed. These three energy sources provide over 99 percent of the energy consumed in the industry. Consumption of energy in the furnace constitutes the major comsumption of energy in the glass industry. Natural gas has been the preferred primary fuel with fuel oil used when natural gas supplies are curtailed. Coal is not presently burned or gasified to provide energy for the glass industry.

There are three types of fossil fuel-fired melting units used in the glass industry: day pots, day tanks, and continuous tanks. Typically, day pots are used where other larger tanks are not economically justifiable because of limited production of special compositions of glass. The range of the capacities of day pots varies from 9 kilograms (20 pounds) to 1,800 kilograms (2 tons) with these quantities melted in 24-hour batches. Although the capacity of a typical day tank is slightly larger than that of a typical day pot, the primary distinction between the two units is the material of construction of the vessel walls.

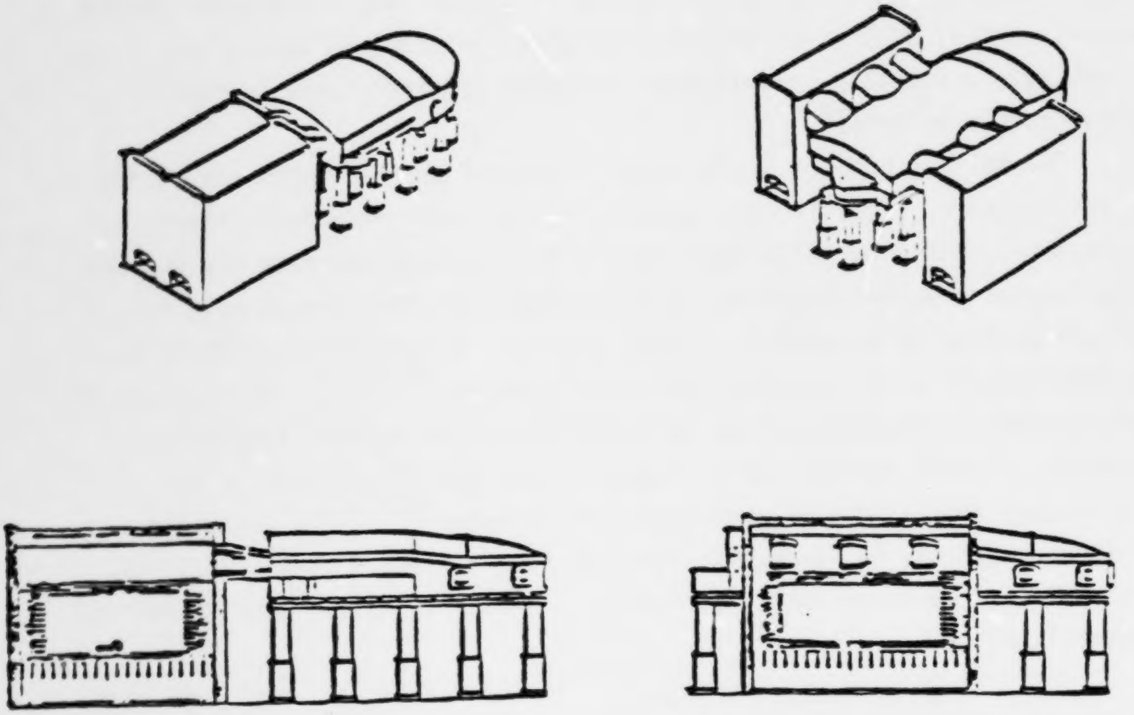
Although day pots and day tanks are used to produce glass, most glass tonnage is melted in larger capacity, continuously operating regenerative or recuperative furnaces. Generally, regenerative furnaces maintain a larger production rate than recuperative furnaces. These types of furnaces differ in the types and modes of operation of the heat exchangers used to recover heat from the furnace exhaust gases.

Regenerative furnaces utilize two chambers of refractory called checkerworks in the following manner. At any one time, while combustion flue gases heat the refractory in one checkerwork chamber, the other checkerwork preheats combustion air; then after intervals ranging from 10 to 30 minutes, this gas flow is diverted so that combustion air is drawn through the chamber previously heated by flue gases. The flue gases heat the refractory in the other chamber previously used to preheat combustion air. Regenerative furnaces, themselves, are divided into two functional categories - side-fired and end-fired furnaces depending on the furnace flame firing pattern. Figure 2-2 illustrates a typical side-fired furnace and an end-fired furnace.

Recuperative furnaces employ one continuously operating shell and tube type heat exchanger to preheat combustion air instead of the checkerwork heat exchangers used in regenerative furnaces.

Regenerative and recuperative furnaces, which are fossil fuel-fired, are being modified and in some cases replaced by systems using electrical current to melt glass. Electric boosting is the term applied to the furnace modification in which an electric current is used to augment furnace firing of gas or oil. Electrical energy is converted to heat because of the high electrical resistance of the molten glass. The effect of electric boosting is to decrease the required furnace bridgewall temperature, which in turn decreases the fuel consumption rate, thereby decreasing the pollutant emission rate.[25]

In some limited applications, more traditional regenerative furnaces have been totally replaced by systems known as all-electric melters. All-electric melters produce less than 10 percent of the glass in the United States and none of the units produce more than 136 Mg (150 tons)/day.[26] The surface of the melter in a cold top all-electric furnace is maintained at ambient temperature, and fresh batch raw materials are continuously fed over the entire surface. Because energy is supplied internally to the glass, a higher percentage of the total energy expended can be converted



END-FIRED BOX TYPE REGENERATIVE GLASS FURNACE

SIDE-FIRED BOX TYPE REGENERATIVE GLASS FURNACE

Figure 2-2. Typical side-port furnace and end-port furnace.

into usable heat for melting than with fossil fuel-fired melters.[27] Pollutant emissions from all-electric melters are virtually nil.[28,29,30,31] The main limitation with these systems is that they cannot be used to produce all varieties of glass. Not all glasses posess the electrical properties required for these melters and some glass formulations actually corrode the electrodes presently used in the all-electric melters.[32]

The melting process is the major source of arsenic emissions in the glass industry. However, the majority of the input inorganic arsenic is permanently fixed in the molten glass and is not emitted from the furnace. The remaining arsenic material is evaporated from the furnace melt and is either eventually emitted as arsenic vapor or it condenses as submicron arsenic particles or on other particulate matter.[33,34,35] The majority of the arsenic particulate matter is entrained in the exhaust flue gas, however, a small portion can be deposited as particle fallout in the refractory checkerwork of a regenerative furnace.[36,37] The extent to which arsenic may be removed in the checkerwork has not been quantified. Recuperative furnaces would, of course, not have a similar arsenic removal capability.

2.3.1.3 Forming and Finishing.[38] In the forming and finishing step, the molten glass is extracted from the furnace, shaped to the desired form, and then annealed at high temperature. The final product is then either inspected and shipped or sent for further finishing such as tempering or decorating.

In practice, the molten glass, while at a yellow-orange temperature, is drawn quickly from the furnace and worked in forming machines by a variety of methods: pressing; blowing in molds; and drawing, rolling, and casting. Immediately, this formed glass is conveyed to continuous annealing ovens to remove internal stresses in the glass by controlled cooling.

The forming and finishing process is not a source of arsenic emissions.

2.4 FACTORS AFFECTING ARSENIC EMISSIONS FROM GLASS MELTING FURNACES

The two major factors affecting arsenic emissions from glass furnaces include (1) the glass type and (2) furnace operation.

2.4.1 Glass Type

The most important factor affecting arsenic emissions in glass plants is the type of glass being produced. In general, the amount of arsenic input to the glass batch will depend on the specific glass type. In addition, different glass types have different arsenic retention properties. One company has provided data on theoretical arsenic input and retention amounts for the various types of glasses it produces.[39] The company also indicated that its glasses are very similar in physical and chemical properties to the glasses produced by its competitors. Based on this information, the theoretical arsenic input and retention data for the major types of glasses using arsenic in the pressed and blown segment would be as shown in Table 2-2.

TABLE 2-2. THEORETICAL ARSENIC INPUT/RETENTION DATA

Glass Type	Theoretical Arsenic Input, kg/Mg Filled[a]	Theoretical Arsenic Retained in Batch, kg/Mg Filled[a]	Theoretical Arsenic Lost, kg/Mg Filled[b]
Lead	1.9	1.8	0.1
Lead Silicate	1.0	0.7	0.3
Fluoride Opal	3.8	3.7	0.1
Alumino Silicate	6.3	5.7	0.6
Borosilicate	6.8	6.2	0.6

[a] $\frac{\text{Amount of glass pulled}}{\text{Amount of glass filled}}$ = 0.85 to 0.93 depending upon the glass type.

[b] Not all theoretical arsenic lost may go out of the stack. Some may be recovered in the slag.

As seen from Table 2-2, percent retention of arsenic ranges from 70 to 99 percent.

2.4.2 Furnace Operation

Another important factor affecting arsenic emissions is the furnace operation. Furnace operation primarily affects particulate emissions from glass furnaces which may impact arsenic emissions. The key operating parameters affecting emissions are the furnace (or bridgewall) temperature, the amount of cullet in the batch, the surface area of the molten glass bed, the production (or pull rate) of glass, and the type of fuel being burned. Of these operating parameters, temperature is the most important. Increasing the temperature over the melt vaporizes more of the volatile materials than at lower temperatures. Maintaining high temperature requires more fuel to be consumed and, therefore, increases the level of pollutants derived from fossil fuels.

Other parameters influence pollutant emission levels by changing the temperature required to maintain production. For example, increasing the cullet proportions in the raw batch lowers bridgewall temperature, thereby, lowering emissions. The amount of surface area of molten glass exposed to combustion gases has been shown to affect particulate emissions. With all other parameters constant, a larger exposed area generates more particulate than a smaller area.[40]

For a furnace producing a single type of glass, increasing the pull rate requires more energy, which if supplied by the combustion of fossil fuels, causes an increase in furnace temperature with a corresponding increase in emissions. As the pull rate increases, the emissions increase at a decreasing rate. In the limiting case of no pull rate, data have been published which show that particulates are still emitted from the molten glass bed.[41] For a soda/lime glass, the emission levels at zero pull rate were found to be roughly 20 percent of those at the normal pull rate with both measurements being taken at the same temperature.

2.5 INORGANIC ARSENIC EMISSIONS OCCURRING UNDER EXISTING REGULATIONS

2.5.1 Existing Regulations

There are currently no regulations at the Federal or State level for arsenic emissions from glass plants. Atmospheric inorganic arsenic emissions from glass plants are presently being controlled indirectly as a result of State and Federal particulate matter regulations. Table 2-3 lists particulate compliance limits for various glass production rates as allowed by states in which most of the glass manufacturing facilities are located.

TABLE 2-3. STATE PARTICULATE REGULATIONS FOR EXISTING STATIONARY SOURCES

Pull Rate Tons/Day	Pull Rate Tons/Hr	Process Weight Tons/Hr	Indiana, Ohio Oklahoma, and Illinois		Texas		California South Coast Air Quality Management District		New Jersey		New York		West Virginia	
			kg/hr	(lb/hr)	kg/hr	(lb/hr)	kg/hr	(lb/hr)	kg/hr	(lb/hr)	kg/hr	(lb/hr)	kg/hr	(lb/hr)
24	1	1.2	2.1	(4.6)	1.7	(3.7)	1.8	(4.0)	2.5	(5.5)	1.9	(4.2)	1.1	(2.4)
50	2.1	2.5	3.4	(7.5)	3.4	(7.5)	2.5	(5.5)	2.8	(6.1)	3.1	(6.8)	2.2	(4.9)
75	3.1	3.7	4.5	(9.8)	5.1	(11.2)	3.1	(6.7)	3.0	(6.6)	4.1	(8.9)	3.4	(7.4)
100	4.2	4.9	5.4	(11.9)	6.8	(14.9)	3.8	(8.4)	3.3	(7.2)	4.9	(10.8)	3.8	(8.3)
150	6.3	7.4	7.1	(15.6)	10.1	(22.3)	4.3	(9.5)	3.8	(8.3)	6.4	(14.2)	5.8	(12.8)
200	8.3	9.8	8.6	(18.9)	13.4	(29.5)	5.0	(10.9)	4.3	(9.4)	7.8	(17.2)	7.2	(15.8)
250	10.4	12.3	10.0	(22.0)	16.7	(36.8)	5.4	(11.8)	4.8	(10.5)	9.0	(19.9)	7.5	(16.5)
300	12.5	14.3	11.3	(24.8)	20.0	(44.0)	5.8	(12.8)	5.3	(11.6)	10.2	(22.5)	8.6	(19.0)

The table entries are calculated for existing Container Glass furnaces assuming that 85 percent of process weight rate is transformed into glass production, which corresponds to the normal 15 to 20 percent cullet usage.[42]

The limits of Illinois, Indiana, New York, Ohio, Oklahoma, and Texas are formulated on a mass basis with an exponential dependence on process weight. California limits are represented by the allowable particulate emissions of the South Coast Air Quality Management District. The New Jersey regulation for glass plants is also determined on a mass basis but with a linear dependence on process weight and with allowances made for increased cullet utilization. The New Jersey Department of Environmental Protection makes an exception to the process weight limits for the case of furnaces producing lead glass where a compliance schedule of 0.02 Gr/SCF applies. West Virginia compliance regulations are interpolated from a table based on process weight. Pennsylvania maintains a concentration basis regulation for flat and container glass and mass basis regulation for pressed, blown, or spun glass.

There is also a new source performance standard (NSPS) for control of particulate emissions from glass melting furnaces. The NSPS emission limits are shown in Table 2-4. These limits are met by installation of add-on control devices such as fabric filters and electrostatic precipitators. The State particulate matter regulations are met by installing an add-on control device, installing an electric boosting process modification, modifying batch formulations, or collecting particulate matter as fallout in the furnace checkerwork. Of these particulate control methods, the use of add-on control devices does the most effective job of reducing arsenic emissions, while the checkerwork fallout technique does the least effective.

TABLE 2-4. NEW SOURCE PERFORMANCE STANDARD FOR PARTICULATE EMISSIONS FROM GLASS FURNACES

	Emission Limit, g of Particulate/kg of Glass Produced	
Glass Manufacturing Plant Industry Sector	Furnace Fired With Gaseous Fuel	Furnace Fired With Liquid Fuel
Container glass	0.100	0.130
Pressed and blown glass		
(a) Borosilicate recipes	0.500	0.650
(b) Soda/lime and lead recipes	0.100	0.130
(c) Other than borosilicate, soda/lime, and lead recipes (including opal, fluoride, and other recipes)	0.250	0.325
Wool fiberglass	0.250	0.325
Flat glass.	0.225	0.225

2.5.2 Baseline Inorganic Arsenic Emissions and Controls

The baseline arsenic emissions are estimated from the available arsenic emissions data for glass furnaces. These data do not represent emissions from all arsenic emitting furnaces in the nation and, therefore, understate the baseline emissions. However, the furnaces not included in the data base are expected to be small furnaces, mainly in the hand pressed and blown glass sector, with relatively low annual arsenic emissions. The baseline emission estimates, therefore, account for most of the total arsenic emissions from glass furnaces. The available estimates of hourly and annual inorganic arsenic emissions from existing furnaces known to produce arsenic-containing glasses are given in Table 2-5. These emissions data are from 32 furnaces at 15 plants. All 32 furnaces meet the applicable state particulate limits. Of the 32 furnaces, 13 have add-on control devices. These include two fabric filters and 11 electrostatic precipitators. Two of the 19 furnaces without add-on control devices have electric boosting. The majority of the arsenic emission estimates were provided by the companies involved and are based on actual measurements in some cases and on material

TABLE 2-5. AVAILABLE INORGANIC ARSENIC EMISSIONS DATA FOR EXISTING ARSENIC-USING GLASS PLANTS[a]

Plant	Furnace	Existing PM Controls that Reduce Arsenic Emissions[b]	Baseline Arsenic Emissions[c]			
			kg/hr	lb/hr	Mg/yr	(tons/yr)
1	A	ESP preceded by evaporative cooler	0.0031	(0.0069)	0.027	(0.03)
	B	ESP preceded by evaporative cooler	0.0007	(0.0015)	0.006	(0.0066)
2	A	ESP	0.0082	(0.018)	0.069	(0.076)
3	A	ESP	0.011	(0.025)	0.089	(0.101)
4	A	None	0.37	(0.81)	3.09	(3.4)
	B	None	0.42	(0.93)	3.53	(3.9)
	C	None	0.09	(0.19)	0.73	(0.8)
	D	None	0.06	(0.14)	0.55	(0.6)
	E	None	0.06	(0.14)	0.55	(0.6)
5	A	None	0.15	(0.33)	1.27	(1.4)
	B	None	0.11	(0.24)	0.91	(1.0)
6	A	None	0.05	(0.12)	0.45	(0.5)
	B	None	0.22	(0.48)	1.82	(2.0)
	C	None	0.37	(0.81)	3.09	(3.4)
7	A	FF	0.023	(0.051)	0.19	(0.21)[d]
8	A	ESP	0.009	(0.02)	0.076	(0.084)
9	A	EB	1.81	(4.0)	15.20	(16.8)[d]
10	A B C D	Total from 4 furnaces None	0.0045	(0.01)	0.038	(0.042)[d]
11	A	ESP preceded by an evaporative cooler	0.0027	(0.006)	0.023	(0.025)[b]
12	A (2 stacks)	None	0.227	(0.5)	1.99	(2.19)
	B (2 stacks)	None	0.273	(0.6)	1.83	(2.01)
	C	ESP preceded by evaporative cooler and a cyclone	0.018	(0.02)	0.073	(0.08)

TABLE 2-5. (Continued)

Plant	Furnace	Existing PM Controls that[b] Reduce Arsenic Emissions[c]		Baseline Arsenic Emissions[a]			
				kg/hr	lb/hr	Mg/yr	(tons/yr)
13	A	Common Stack					
	B		ESP preceded by evaporative cooler	0.005	(0.01)	0.038	(0.042)
	C						
	D		ESP preceded by evaporative cooler	0.0227	(0.05)	0.191	(0.21)
14	A	EB		0.091	(0.2)	0.76	(0.84)
	B	FF		0.004	(0.01)	0.038	(0.042)
15	A		None	0.014	(0.03)	0.118	(0.126)[d]
					Total	36.70	(40.50)

[a] References 43, 44, 45, 46, 47.

[b] FF = fabric filter
ESP = electrostatic precipitator
EB = electric boosting
PM = particulate matter

[c] Emissions expressed as total elemental arsenic.

[d] For furnaces where no information was available on the exact hours of operation, 8,400 hr/yr was assumed.

balance calculations in others. Several of these furnaces produce many different types of glasses, only some of which contain arsenic. The annual emissions shown for these furnaces take into account the production schedules of arsenic-containing glasses. Total existing arsenic emissions from the 32 furnaces are about 37 Mg (41 tons)/yr.

2.6 REFERENCES

1. Spinosa, E. D., et al. (Battelle Columbus Laboratories.) Summary Report on Emissions from the Glass Manufacturing Industry. (Prepared for the U. S. Environmental Protection Agency.) Cincinnati, Ohio. Publication No. EPA-600/2-79-101. April 1979. 49 p.

2. Bauer, R. J. Arsenic: Glass Industry Requirements. In: Arsenic: Proceedings of the Arsenic Symposium, Lederer, W. H. and Fensterheim, R. J. (ed.) Gaithersberg, Maryland, Van Nostrand Reinhold Company. 1983. p. 47.

3. Peters, A. The Use of Arsenic with Particular Reference to the Glass Industry. Glastechn. Ber. (Mainz, Germany). 50(12):328-335. 1977.

4. Reference 1, p. 7.

5. Reference 1, pp. 10-16.

6. U. S. Environmental Protection Agency. Glass Manufacturing Plants Background Information: Proposed Standards of Performance. Research Triangle Park, N. C. Publication No. EPA-450/3-79-005a. June 1979. p. 8-20.

7. Reference 3.

8. Reference 3.

9. Reference 3.

10. Reference 3.

11. Reference 3.

12. Reference 3.

13. Crose, P. (Acurex Corporation.) Arsenic: An Environmental Materials Balance- Draft Final Report. (Prepared for U. S. Environmental Protection Agency.) Washington, D. C. EPA Contract No. 68-01-6017. March 1981. pp. 3-3, 3-14.

14. PEDCo Environmental, Inc. Extended Source Survey Report for Arsenic. (Prepared for U. S. Environmental Protection Agency.) Research Triangle Park, N. C. EPA Contract No. 68-02-3173. May 1982. pp. 3-31 to 3-33.

15. Reference 6. p. 3-10.

16. Letter from Cherill, J., Corning Glass Works to Hellwig, G. V., PEDCo Environmental. June 1, 1981. 2 p. Information on Corning's glass composition changes since 1978.

17. Telecon. Armstrong, F., RCA Corporation, with Brooks, G., Radian Corporation. February 19, 1982. Conversation concerning arsenic usage by RCA.

18. Reference 16.

19. Reference 6. p. 3-5.

20. Letter from Mosely, G., Corning Glass Works to O'Connor, J., EPA:MDAD. August 28, 1978. 4 p. Information on arsenic in glass and arsenic emissions from glass melting units.

21. Reference 6. p. 3-10.

22. Schorr, J. R., et al. (Battelle-Columbus Laboratories.) Source Assessment: Pressed and Blown Glass Manufacturing Plants. (Prepared for U. S. Environmental Protection Agency.) Research Triangle Park, N. C. Publication No. EPA-600/2-77-005. January 1977. p. 34.

23. Reference 22.

24. Reference 6. pp. 3-6 to 3-8.

25. Reference 6. p. 4-4.

26. Reference 22.

27. Reference 22.

28. Reference 22.

29. Memo from Cuffe, S., EPA:ESED, to O'Connor, J., EPA:MDAD. July 17, 1978. 2 p. Emissions of arsenic from glass melting furnaces.

30. Memo from Herring, W., EPA, to Cuffe, S., EPA:ESED. December 27, 1978. 2 p. Arsenic emissions from glass manufacturing plants.

31. Telecon. Cherill, J., Corning Glass Works, with Brooks, G., Radian Corporation. January 29, 1982. Conversation about Corning's use of arsenic.

32. Reference 6. p. 4-6 to 4-7.

33. Reference 3.

34. Reference 6. p. 3-16.

35. Suta, B. E. (SRI International.) Human Exposures to Atmospheric Arsenic. (Prepared for U. S. Environmental Protection Agency.) Research Triangle Park, N. C. EPA Contract Nos. 68-01-4314 and 68-02-2835. May 1980. p. 97.

36. Reference 20.

37. Letter and attachments from Swander, T., RCA Corporation, to Goodwin, D., EPA:ESED. September 27, 1978. 8 p. Information on arsenic in glass and arsenic emissions from glass manufacturing units.

38. Reference 6, pp. 3-8 to 3-10.

39. Reference 20.

40. Reference 6, pp. 3-17 to 3-18.

41. Reference 22, pp. 46 - 48.

42. Reference 6, p. 3-23.

43. Memo from Shareef, S. A., Radian Corporation, to file. April 7, 1983. 1 p. Emissions data on glass furnaces at RCA Corporation.

44. Letter from Goebel, G., Kentucky Bureau of Environmental Protection, to Brooks, G., Radian Corporation. February 11, 1982. 2 p. Information on inorganic arsenic emissions from Corning Glass Works plant in Danvile.

45. Telecon. Iden, C., Owens-Illinois, with Brooks, G., Radian Corporation. March 3, 1982. Conversation about Owens-Illinois arsenic emissions.

46. Letter and attachments from Murray, D. E., Anchor Hocking Corporation, to Shareef, S. A., Radian Corporation. March 14, 1983. 5 p. Information on inorganic arsenic emissions from Anchor Hocking glass plants. (Project Confidential Files.)

47. Letter and attachments from Cherill, J., Corning Glass Works, to Brooks, G., Radian Corporation. April 7, 1982. 19 p. Information on inorganic arsenic emissions from Corning Glass Works plants. (Project Confidential Files.)

3.0 EMISSION CONTROL TECHNIQUES

As discussed in Chapter 2 of this document, the arsenic material that does not get permanently fixed in the molten glass or in the slag, is evaporated from the furnace melt. The arsenic is either eventually emitted as vapor, as condensed submicron arsenic particles, or as arsenic condensed on other particulate matter. Control techniques that reduce particulate emissions would, therefore, reduce emissions of arsenic. The overall reduction in arsenic emissions would depend on the effectiveness of the particulate control device as well as the relative quantities of vapor phase and solid phase arsenic in the flue gas stream at the inlet to the particulate control device. The two major methods applicable to particulate and, therefore, arsenic control in the glass manufacturing industry are (1) process modifications and (2) add-on control techniques.

3.1 PROCESS MODIFICATIONS

Process modifications lower glass melting furnace emissions either by altering raw material recipes or by modifying furnace equipment. These modifications are discussed below.

3.1.1 Batch Formulation Alterations

The glass industry has greatly reduced, in the past years, the amount of arsenic used in glass products. The flat glass industry reports that the use of arsenic has been eliminated completely in this segment of the industry.[1,2,3,4,5] Arsenic use has also been almost eliminated in the container glass industry. However, at present there is at least one speciality container glass plant known to be using arsenic. One source reports that the various oxidation states of sulfur make it the most commonly used fining agent for soda-lime glasses which dominate the flat and container glass segments.[6]

The pressed and blown glass industry is the largest user of arsenic in the glass industry. However, arsenic use by this segment of the industry has also been completely eliminated for some glass products. In many other products arsenic input is reported to have already been reduced to the extent possible.[7] The most commonly used substitute is antimony. As an oxygen generator, it is a very effective fining agent for lead glasses at temperatures below 1400°C (2550°F). Antimony is used in some glasses as antimony trioxide, and in most commercial high volume production as sodium antimonate. The use of arsenic and antimony together is considered to be more effective than when either is used alone. However, antimony is not considered to be an effective fining agent in many of the opal and ceramic glasses either alone or in combination with other agents.[8]

The halogens, especially chloride and fluoride, are used in many glasses as fining agents. Chloride fining, usually as sodium and potassium salts, is used in the hard borosilicate glasses. However, it does not control redox and can, with water and alkali-boron balances in the process, create particulate air pollution problems.[9] Fluoride can also cause air pollution and is also ineffective at high temperatures.

Other metal oxides, especially tin when used with antimony oxides, have shown some desirable attributes in fining and redox control with some glasses. However, this combination has not yet been shown to produce an equivalent product to that produced using arsenic and is not considered a replacement.[10]

No data are available to quantify the reduction in arsenic emissions that can be achieved due to batch formulation alterations. However, the use of arsenic in the glass industry decreased by more than 80 percent between 1968 and 1981.[11,12]

3.1.2 Electric Boosting

Electric boosting is the term applied to the technique of augmenting melting in a fossil-fuel-furnace by dissipating electrical current through the molten glass. Electrical energy is converted to heat because of the high electrical resistance of the molten glass. For a fixed furnace throughput, utilizing electric boosting decreases the required bridgewall temperature, decreasing the fuel consumption rate, and thereby decreasing both particulate and gaseous pollutant levels. Boosting has normally been used to increase production rate since it does not require substantial modifications of the furnace. However, as mentioned in Chapter 2, not all glasses possess the electrical properties required for these melters and the use of electric boosting is limited.

There are presently two furnaces known to be producing arsenic-containing glasses that use electric boosting. Emissions data provided by the plants indicate that arsenic emissions were reduced by 45 and 60 percent by the use of electric boosting.[13] Table 3-1 shows the uncontrolled and controlled emission rates for the two furnaces using electric boosting.

TABLE 3-1. EFFECT OF ELECTRIC BOOSTING ON ARSENIC EMISSIONS FROM GLASS FURNACES

		UNCONTROLLED ARSENIC EMISSIONS		CONTROLLED ARSENIC EMISSIONS		
PLANT	FURNACE	kg/hr	(lb/hr)	kg/hr	(lb/hr)	PERCENT REDUCTION
9	A	4.55	(10.0)	1.81	(4.0)	60
14	A	0.17	(0.36)	0.091	(0.2)	45

3.1.3 All-Electric Melters[14]

In contrast to conventional fuel-fired furnaces, the surface of the melter in a cold top all-electric furnace is maintained at ambient temperature, and fresh raw batch materials are fed continuously over the entire surface. As molten glass is withdrawn from the melter, raw batch drops in the melter, gradually heats up, and finally reacts in the liquid phase. This processing minimizes losses from vaporization. The gases discharged through the batch crust consist of carbon dioxide and water vapor.

Design objectives for all-electric melters have not been based primarily on emission control, but rather on efficient melting and product control. Construction is less expensive than that for fossil fuel furnaces since there are no regenerator chambers, port necks, checkers, flues, or reversing valves, and stacks can be eliminated. Additionally, there is no need for ductwork, combustion blowers, fans, extra piping, burners, or special refractory shapes.

Accomplishment of design objectives results in a low surface temperature and a finer control on the glass melt formulation and, therefore, relatively low levels of emissions. Presently no data are available for arsenic emissions from all-electric glass furnaces. As with electric boosting the potential for all electric melting is limited by the required electrical properties of the glass.

3.2 ADD-ON CONTROL TECHNIQUES

Add-on control techniques applicable to glass furnaces include fabric filters (FF), electrostatic precipitators (ESP), and scrubber systems. Of the 32 arsenic emitting furnaces listed in Table 2-5, 11 are equipped with electrostatic precipitators and two have fabric filters. The three add-on control techniques are discussed below.

3.2.1 Fabric Filters[15]

Several glass manufacturing facilities utilize fabric filter systems to collect particulates in the glass melting furnace exhaust. In these systems, the furnace exhaust is first cooled and then passed through a fabric filter which retains particulate, and allows the gases to vent to the atmosphere. The physical characteristics of the filtering fabrics and the agglomerating tendency of submicron particles have made the fabric filter systems viable control techniques for the collection of glass melting furnace particulates.

Figure 3-1 illustrates a typical baghouse system. In operation, a fan pulls the furnace gases through devices which cool the gases to a temperature compatible with the filter material. Cooling is accomplished by duct cooling, dilution air addition, or water injection. The gases are then

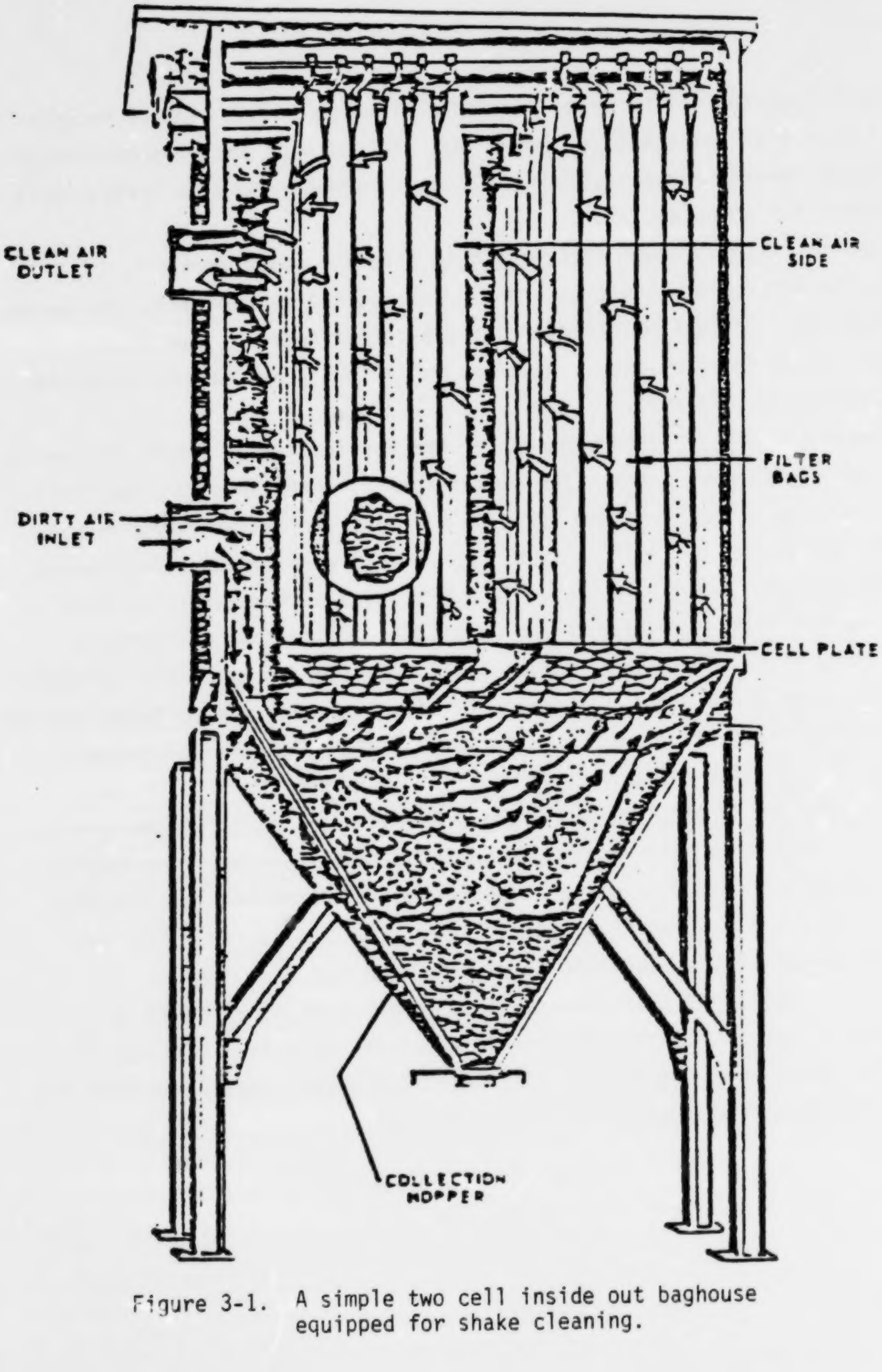


Figure 3-1. A simple two cell inside out baghouse equipped for shake cleaning.

forced through the filter bags. Periodic cleaning of the bags is necessary to maintain high collection efficiencies. Filter bags are cleaned through shaking or reverse air pulsations. Conveyors transfer the collected dusts to hoppers for disposal.

Fabric filter systems are claimed to have the advantages of: high collection efficiency; low pressure drop across the system; and, low energy requirements. Collection efficiencies are not affected by the electrical resistivity of the particles. Bag life is up to 2 years depending on the bag construction material.

There are certain disadvantages to the application of fabric filters to glass melting furnace gases. The temperature of gases entering the fabric filter must be below a maximum value to minimize thermal degradation and prevent melting of the fabric as well as above a minimum value to prevent condensation of sulfur trioxides. In addition, a high moisture content of the gases can form an irremovable plug within a filter bag by blinding.

Fabric filters have been successfully demonstrated to control arsenic emissions from glass plants. Arsenic emissions testing was performed by the Environmental Protection Agency on a fabric filter installed on a glass furnace.[16] The testing method employed was "Reference Method for the Determination of Particulate and Gaseous Arsenic Emissions from Non-Ferrous Smelters", Method No. 108, with some approved modifications. The samples collected were analyzed for arsenic using atomic absorption spectrophotometry. The overall arsenic control efficiency of the fabric filter was about 93 percent. Detailed results of this test are presented in Appendix C. Emissions data provided by another plant also showed an estimated 93 percent control of arsenic emissions by a fabric filter.[17] Table 3-2 shows the uncontrolled and controlled arsenic emissions from the two glass furnaces equipped with fabric filters.

TABLE 3-2. PERFORMANCE OF FABRIC FILTERS ON ARSENIC EMISSIONS FROM GLASS FURNACES

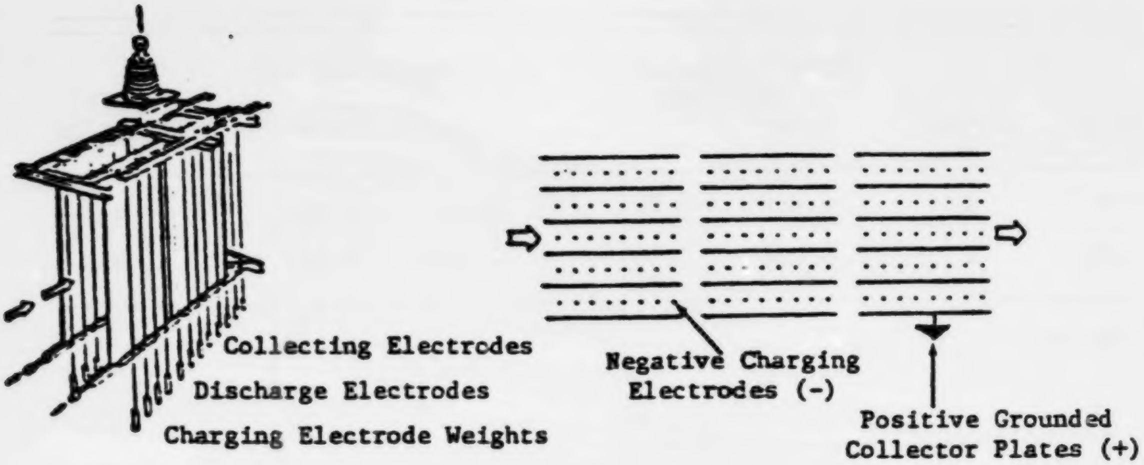
PLANT	FURNACE	UNCONTROLLED ARSENIC EMISSIONS kg/hr	UNCONTROLLED ARSENIC EMISSIONS (lb/hr)	CONTROLLED ARSENIC EMISSIONS kg/hr	CONTROLLED ARSENIC EMISSIONS (lb/hr)	PERCENT REDUCTION
7	A	0.291	(0.65)	0.023	(0.051)	93
14	B	0.068	(0.15)	0.004*	(0.01)	93

*Estimated emissions.

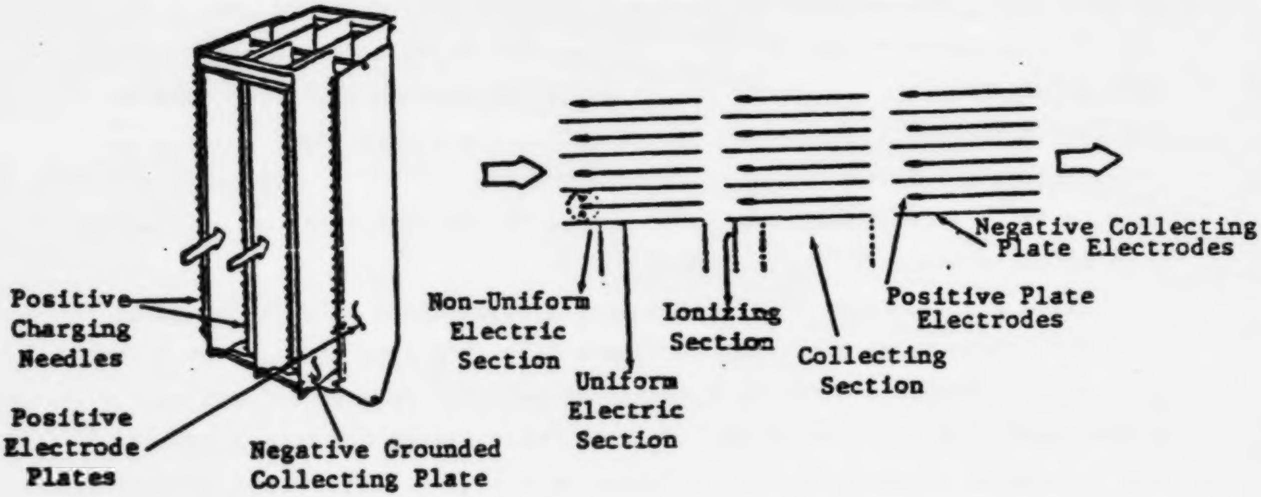
3.2.2 Electrostatic Precipitators[18]

Electrostatic precipitators are the most widely used particulate control technique in the glass manufacturing industry. The fundamental steps of electrostatic precipitation are particle charging, collection, and removal and disposal of the collected material. Particulate charging is accomplished by generating charge carriers which are driven to the particulates by an electric field. Collection occurs as the charged particulates migrate to electrodes to which the charged particles adhere. Applying a mechanical force to the collection electrodes dislodges the collected material which then falls into hoppers. Effective transfer of dust to the hopper depends on the formation of agglomerations of dust which fall with a minimum of reentrainment.

There are two types of electrostatic precipitators used in the glass industry. Both types are shown in Figure 3-2. One type consists of a large rectangular chamber divided by a number of parallel rows of collection plates that form gas flow ducts. Between these plates are hung a number of small diameter wires which are connected to a high voltage direct current potential forming a corona discharge around the wire. This corona generates electrons which migrate into the incoming gas stream to form gas ions which attach to these particles. The charged particles, in turn, are collected by the grounded collection plates.


Collecting Electrodes
Discharge Electrodes
Charging Electrode Weights
Negative Charging Electrodes (-)
Positive Grounded Collector Plates (+)

Conventional Electrostatic Precipitator


Positive Charging Needles
Positive Electrode Plates
Negative Grounded Collecting Plate
Non-Uniform Electric Section
Uniform Electric Section
Ionizing Section
Collecting Section
Positive Plate Electrodes
Negative Collecting Plate Electrodes

Needle Type Electrostatic Precipitator

Figure 3-2. Conventional and needle type electrostatic precipitators.

The other type of ESP has a multitude of stainless steel needles fastened to the leading and trailing edge of the discharge plates. This design configuration requires a low voltage which allows close spacing between the two collecting surfaces in each field: the positively charged discharge plates, which have the attached needles; and, the grounded collector plates. This close plate spacing permits short collecting sections and relatively high flow velocities. Additionally, the regions between the needles exhibit a uniform electric field which aid particle agglomeration. Dust is retained on both the collector plates and discharge plates.

Resistivity of the particulate is a determining design parameter. If the resistivity of the particles is very high ($\geq 2 \times 10^{10}$ ohm-cm), the dust layer accumulating on the collection plates must not be allowed to build up to the thickness typical for a lower resistivity particle. If this occurs, excessive sparking might result. Under these conditions, the applied voltage might have to be reduced, and the resulting decrease in both corona current and electrical field would lower the collection efficiency. Particles with very low resistivity will also adversely affect the ESP performance. If the resistivity of the particles is less then 2×10^{7} ohm-cm, the electrical forces holding the dust cake onto the collecting plates are weaker than with particles of higher resistivity. As a result, more of the particles will be reentrained and the emissions will be higher. Some typical resistivity figures for various types of glass are:

Borosilicate glass	10^{12} ohm - cm
Lead glass	10^{11} ohm - cm
Soda-lime glass	10^{7} to 10^{10} ohm - cm (Depending on temperature and moisture content)

Electrical resistivity decreases as temperature increases. Depending upon the glass type, the operating temperature may be increased or decreased to obtain the optimal performance from an electrostatic precipitator.

Electrostatic precipitators are being used on several furnaces melting arsenic containing glasses and have shown high control efficiencies on arsenic. The Environmental Protection Agency has performed arsenic emission test on one glass furnace equipped with an electrostatic precipitator.[19] The testing method employed was "Reference Method for the Determination of Particulate and Gaseous Arsenic Emissions from Non-Ferrous Smelters", Method No. 108, with some approved modifications. The samples collected were analyzed for arsenic using atomic absorption spectrophotometry. Due to the lack of test ports at the inlet to the electrostatic precipitator, the uncontrolled emissions were measured at the outlet with the electric current to the precipitator turned off. The electrostatic precipitator was found to reduce arsenic emissions by about 99 percent. Detailed results of this test are presented in Appendix C.

Several other electrostatic precipitators are also installed on furnaces producing arsenic containing glasses. Emissions data provided by plants for these furnaces indicate that electrostatic precipitators reduced arsenic emissions by 90 to 99 percent. One other plant reported 95 percent reduction on particulate emissions.[20] In general, the reduction efficiency of particulate control devices on arsenic can be expected to be similar to that on total particulates. One company reports that its electrostatic precipitators perform highly selectively on arsenic and lead, and achieve higher retention than on total particulates.[25] The uncontrolled and controlled arsenic emissions data for electrostatic precipitators are presented in Table 3-3.

3.2.3 Scrubber Systems[26]

Although scrubber systems have been built to control particulate emissions in the glass industry, presently only a few devices are in use to control container glass emissions. The most common system in operation is the venturi scrubber. A typical venturi scrubber is shown in Figure 3-3. In a venturi scrubber, particle-laden gases are accelerated through a restriction in the ducting where water is injected into the gas stream. The velocity of the gas stream provides the dual function of atomizing the scrubbing fluid while at the same time providing a differential velocity between particles and the resulting liquid droplets. By utilizing high

TABLE 3-3. PERFORMANCE OF ELECTROSTATIC PRECIPITATORS ON ARSENIC EMISSIONS FROM GLASS FURNACES[a]

PLANT	FURNACE	UNCONTROLLED ARSENIC EMISSIONS kg/hr	UNCONTROLLED ARSENIC EMISSIONS (lb/hr)	CONTROLLED ARSENIC EMISSIONS kg/hr	CONTROLLED ARSENIC EMISSIONS (lb/hr)	PERCENT REDUCTION
1	A	0.07	(0.144)	0.0031	(0.0069)	95
1	B	0.02	(0.0514)	0.0007	(0.0015)	97
3	A	0.37	(0.81)	0.011	(0.025)	97
8	A	0.30	(0.66)	0.009	(0.02)	97
11	A	0.79	(1.74)	0.0027	(0.006)	99
12	C	1.80	(3.96)	0.018	(0.04)	99
13	A B C } Common Stack	0.05	(0.11)	0.005	(0.01)	90
13	D	0.378	(0.83)	0.0227	(0.05)	94

[a] References: 21, 22, 23, 24.

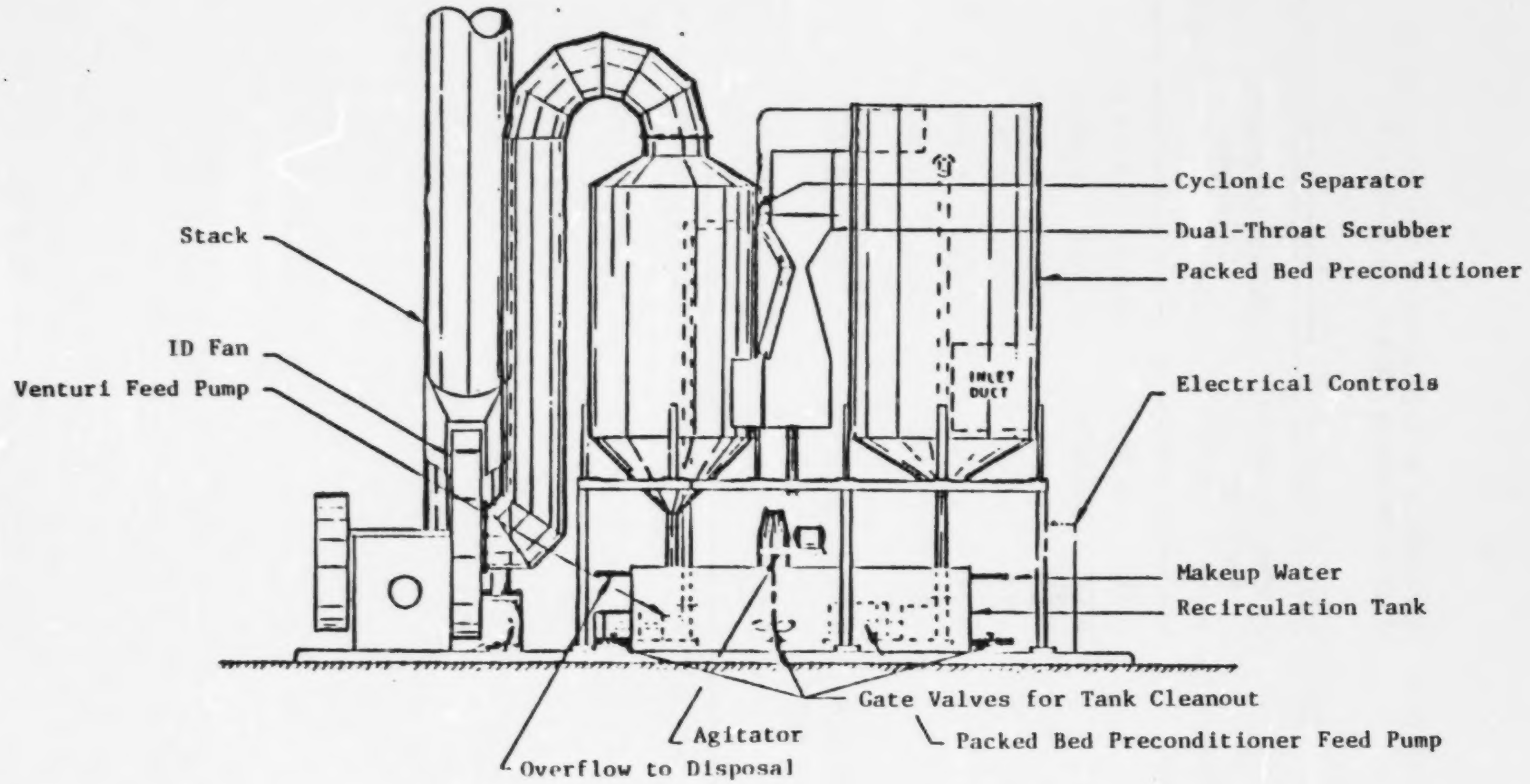


Figure 3-3. Typical scrubber system.

power fans to accelerate the gas stream, it is possible to generate high gas velocities at the throat of the venturi. Since the particulates are mostly water soluble, the scrubber provides a means of removing these emissions. Additionally, some gases are absorbed as condensables.

The scrubber liquor is acidic due to the absorbed acid gases. Before being recycled to the venturi, the pH of the liquor is controlled by caustic solution injection. A bleed stream and makeup water addition insure that the scrubber liquor is not saturated. Typically, a bleed rate of 1.3×10^{-4} m^3/s (2 GPM) is discharged for a 2.1 kg/s (200 TPD) container glass plant. Even for a larger furnace, the bleed rate would be expected to be less than 3.2×10^{-4} m^3/s (5 GPM).

The pressure drop to obtain high velocities in the throat of a scrubber is directly proportional to the gas velocity squared and the liquid-to-gas ratio; therefore, high velocities are possible only at substantial pressure drops which result in high fan energy expenditures. Typical pressure drops are approximately 7,500 Pa (30 inches of water).

None of the scrubber systems in the glass industry is currently used on furnaces melting arsenic glasses.

3.3 EFFECT OF GAS COOLING ON ARSENIC EMISSIONS CONTROL

As discussed in Chapter 2, inorganic arsenic compounds are used in glass manufacturing for a combination of reasons depending on the particular glass being produced. In the majority of cases arsenic compounds act as fining (clarification) or decolorizing agents. Arsenic is added to the glass batch in the form of powdered arsenic trioxide (As_2O_3) or liquid arsenic acid (H_3AsO_4).

From the theoretical considerations presented in Section 2.2, it can be expected that essentially all the arsenic in the batch eventually converts to the trivalent stage, As_2O_3. Therefore, the emissions of arsenic would be in the form of As_2O_3. The relative quantities of As_2O_3 in vapor and solid phase would depend on the temperature of the flue gas. Table 3-4 shows the vapor pressure data for arsenic trioxide. Due to the high volatility of arsenic trioxide, a large portion may exist in the vapor phase in the flue gas from glass furnaces. As the gas is cooled and

TABLE 3-4. ARSENIC TRIOXIDE (ARSENOLITE) VAPOR PRESSURE DATA[27,28]

Vapor Pressure (mm of Hg)	Equilibrium Vapor Phase Concentration (mg As/m^3)	Temperature of Arsenic Trioxide (°C)
2.4×10^{-7}	3.9×10^{-3}	60-61
2.5×10^{-5}	4.0×10^{-1}	81-86
4.6×10^{-4}	7.4×10^{0}	101-105
1.9×10^{-3}	3.1×10^{1}	117-124
2.2×10^{-3}	3.5×10^{1}	119-124
2.6×10^{-2}	4.2×10^{2}	149-152
1.0×10^{-2}	1.6×10^{2}	153.5
2.7×10^{-2}	4.3×10^{2}	165
1.0×10^{0}	1.6×10^{4}	212.5
5.0×10^{0}	8.1×10^{4}	242.6
1.0×10^{1}	1.6×10^{5}	259.7
2.0×10^{1}	3.2×10^{5}	279.2
4.0×10^{1}	6.4×10^{5}	299.2
6.0×10^{1}	9.7×10^{5}	310.3
1.0×10^{2}	1.6×10^{6}	332.5
2.0×10^{2}	3.2×10^{6}	370.0
4.0×10^{2}	6.4×10^{6}	412.2
7.6×10^{2}	1.2×10^{7}	457.2

saturation (equilibrium vapor phase concentration) is achieved, some arsenic trioxide condenses to the solid phase. Theoretically, this cooling is essential for the particulate control device to be effective in controlling arsenic emissions. Figure 3-4 shows that in tests performed on various arsenic sources at copper smelters, cooling the gas resulted in condensation of arsenic to final vapor concentration close to the saturation line. This indicates that arsenic emissions from copper smelters are in the form of arsenic trioxide.

However, in spite of the theoretical considerations for glass furnaces (which also suggest arsenic trioxide emissions), available test data provide conflicting information. For example, EPA tests on the ESP at furnace 11A showed the inlet concentration of total arsenic (vapor and solid phase arsenic) to the ESP was about 0.014 gm/m^3 at 207°C.[29] The vapor phase equilibrium concentration at this temperature is about 16 gm/m^3, indicating that all the arsenic in the flue gas could be accomodated in the vapor phase. However, the ESP outlet concentration showed 99 percent reduction in total arsenic emissions. This level of control indicates that almost all the arsenic was in solid phase. This was further verified by the fact that essentially all of the arsenic was collected in the front half of the stack sampling train (probe and filter) which was maintained at 121°C (250°F). At this temperature about 0.035 gm/m^3 of arsenic (or all of the 0.014 gm/m^3 of total arsenic in the gas) is predicted to be in the vapor phase and should have passed through the filter to be collected in the back half impingers.

Similarly, the test results on the fabric filter at furnace 7A indicate that the total inlet arsenic concentration to the fabric filter (at about 238°C) was only about 6 percent of the equilibrium vapor phase concentration at this temperature.[30] This indicates that all the arsenic in the gas could be accomodated in the vapor phase. However, the stack sampling train collected about 93 percent of the total arsenic in the front half filter. The total arsenic emission reduction achieved by the fabric filter was also about 93 percent.

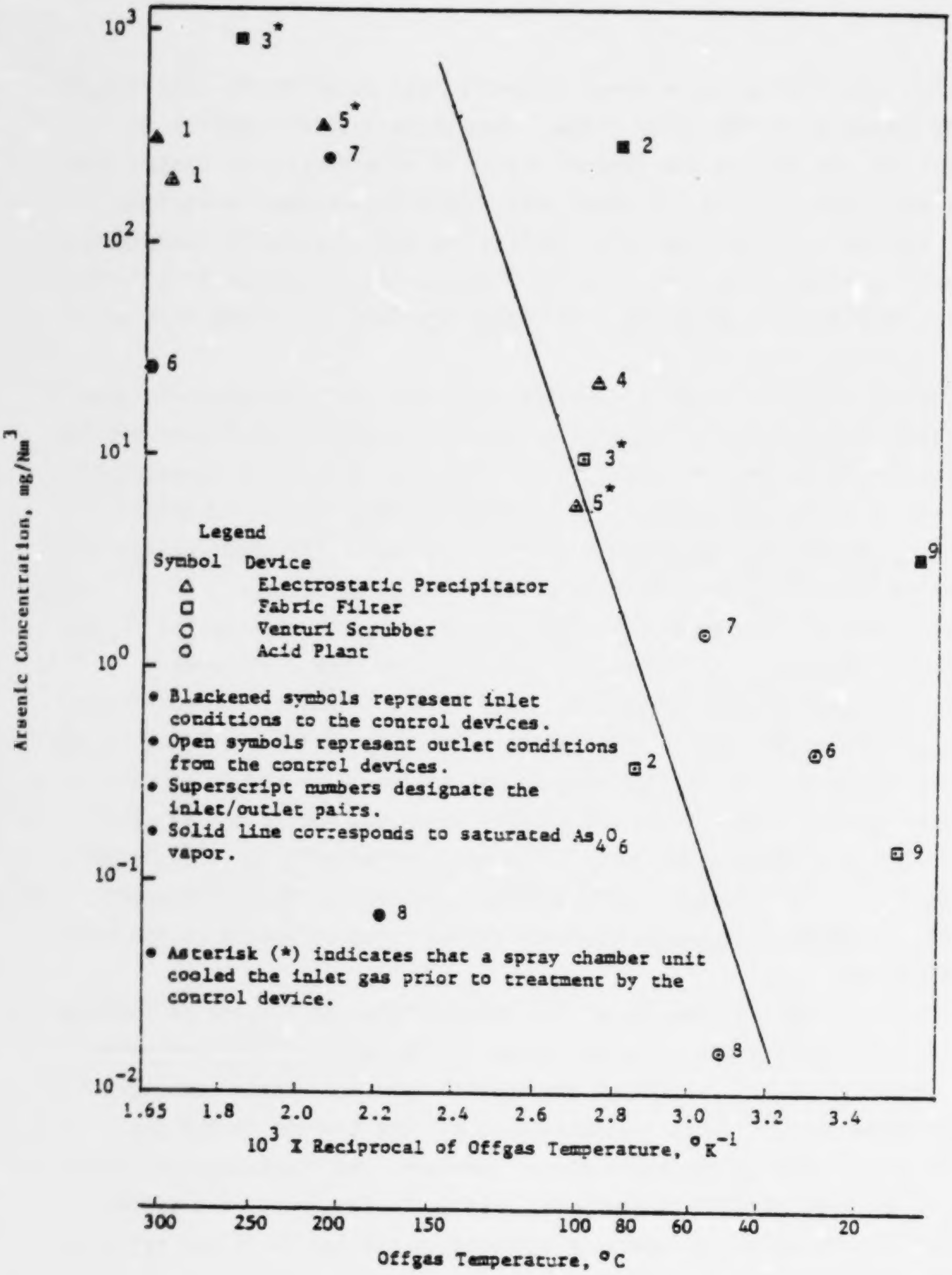


Figure 3-4. Effect of temperature on the performance of arsenic emissions control devices on copper smelters.[31]

The test data, therefore, indicate that at about 200 - 250°C temperature range, greater than 90 percent of the arsenic emissions are in the solid phase. In addition, at these temperatures particulate control devices achieve greater than 90 percent reduction in total arsenic emissions.

The total concentration of arsenic at the above temperature levels was lower than that necessary to cause saturation of arsenic trioxide. There are several possible reasons why, in spite of the low concentrations, greater than 90 percent of the arsenic was in the solid phase. One possible reason may be that the presence of other cations and anions in the batch interfere with the physical behavior of pure arsenic trioxide. Another possible reason may be that the final form of the arsenic emissions is not in the form of arsenic trioxide. The presence of various substances such as nitrates, chlorides, and fluorides may cause formation of one or more stable arsenic compounds that are in the solid phase at the 200 - 250°C temperature range. In particular, the final form of arsenic emissions may be in the form of arsenic pentoxide which is considerably less volatile than arsenic trioxide. Yet another possible reason may be the adsorption of arsenic trioxide on other particulate matter.

In general, based on emission factors for various glass types presented in Table 2-2, the concentration of arsenic in flue gases from glass furnaces will be below the saturation line shown in Figure 3-4. Due to practical considerations such as acid dew point, glass furnace flue gases may not be cooled much below 121°C (250°F). Even at this temperature level, arsenic concentrations will not be high enough to cause saturation if the arsenic compound is arsenic trioxide. Therefore, cooling the gas from glass furnaces would not have the same beneficial effect in reducing arsenic emissions (even if all arsenic was in the vapor phase) as in the case of copper smelters. In any case, since due to one or more of several possible reasons discussed earlier, greater than 90 percent of the total arsenic is in the solid phase, the theoretical maximum condensation due to cooling is limited to less than 10 percent of the total arsenic.

3.4 REFERENCES

1. Telecon. Koralewski, T., Libby-Owens-Ford Company, with Fidler, K., Radian Corporation. February 7, 1983. Conversation about flat glass plant.

2. Telecon. Leroy, A., Fourco Glass Company, with Fidler, K., Radian Corporation. February 7, 1983. Conversation about flat glass plant.

3. Telecon. Havran, D., Combustion Engineering (Glass Division), with Fidler, K., Radian Corporation. February 8, 1983. Conversation about flat glass plant.

4. Telecon. DeNormandie, R. L., AFG Industries, Inc., with Fidler, K., Radian Corporation. February 8, 1983. Conversation about flat glass plant.

5. Telecon. Sherron, T., Ford Motor Company (Glass Division), with Fidler, K., Radian Corporation. February 8, 1983. Conversation about flat glass plant.

6. Bauer, R. J. Arsenic: Glass Industry Requirements. In: Arsenic: Proceedings of the Arsenic Symposium, Lederer, W. H. and Fensterheim, R. J. (ed.) Gaithersberg, Maryland, Van Nostrand Reinhold Company. 1983. p. 52.

7. Draft trip report. S. A. Shareef, Radian Corporation, to file. March 8, 1983. 4 p. Report of March 2, 1983 visit to Corning Glass Works in Corning, New York.

8. Reference 6, p. 51 - 52.

9. Reference 6, p. 52.

10. Reference 6, p. 52.

11. Crose, P. (Acurex Corporation.) Arsenic: An Environmental Materials Balance - Draft Final Report. (Prepared for U. S. Environmental Protection Agency.) Washington, D. C. EPA Contract No. 68-01-6107. March 1981. pp. 3-3, 3-14.

12. PEDCo Environmental, Inc. Extended Source Survey Report for Arsenic. (Prepared for U. S. Environmental Protection Agency.) Research Triangle Park, N. C. EPA Contract No. 68-02-3173. May 1982. pp. 3-31 to 3-33.

13. Letter and attachments from Cherill, J., Corning Glass Works, to Brooks, G., Radian Corporation. April 7, 1982. 19 p. Information on inorganic arsenic emissions from Corning Glass Works plants.

14. U. S. Environmental Protection Agency. Glass Manufacturing Background Information: Proposed Standards of Performance. Research Triangle Park, N. C. Publication No. EPA-450/3-79-005a. June 1979. pp. 4-6 to 4-8.

15. Reference 14, pp. 4-9 to 4-13.

16. Thalman, M. T., et al. (Monsanto Research Corporation.) Arsenic Glass Manufacturing Emission Test Report at Corning Glass Works, Central Falls, Rhode Island. (Prepared for U. S. Environmental Protection Agency.) Research Triangle Park, N. C. Publication No. EMB Report 78-GLS-3. February 1979.

17. Reference 13.

18. Reference 14, pp. 4-19 to 4-21.

19. Thalman, M. T., et al. (Monsanto Research Corporation.) Arsenic Glass Manufacturing Emission Test Report at Corning Glass Works, State College, Pennsylvania. (Prepared for U. S. Environmental Protection Agency.) Research Triangle Park, N. C. Publication No. EMB Report 78-GLS-4. February 1979.

20. Letter from Goebel, G., Kentucky Bureau of Environmental Protection, to Brooks, G., Radian Corporation. February 11, 1982. 2 p. Information on inorganic arsenic emissions from Corning Glass Works plant in Danville, Kentucky.

21. Memo from Shareef, S. A., Radian Corporation, to file. April 7, 1983. 1 p. Emissions data on glass furnaces at RCA Corporation.

22. Telecon. Iden, C., Owens-Illinois, with Brooks, G., Radian Corporation. March 3, 1982. Conversation about inorganic arsenic emissions from Owens-Illinois glass plants.

23. Reference 13.

24. Reference 19.

25. Letter from Armstrong, F. L., FCA Corporation, to Brooks, G., Radian Corporation. March 8, 1982. 1 p. Information on corrected estimate of arsenic emissions.

26. Reference 14, pp. 4-14 to 4-16.

27. U. S. Environmental Protection Agency. Arsenic Emissions from Primary Copper Smelters - Background Information for Proposed Standards. Research Triangle Park, N. C. Draft EIS. February 1981. p. 4-2.

28. Reimers, J. W. and Associates, Ltd. Study of the Emission Control Technology for Arsenic in the Nonferrous Metallurgical Industry. (Prepared for the Air Pollution Control Directorate - Environment Canada.) January 1977. p. 24.

29. Reference 19.

30. Reference 16.

31. Radian Corporation. Preliminary Study of Sources of Inorganic Arsenic. (Prepared for U. S. Environmental Protection Agency.) Research Triangle Park, N. C. Publication No. EPA-450/5-82-005. August 1982. p. 11.

4.0 MODEL FURNACES AND REGULATORY ALTERNATIVES

Model furnaces for the glass manufacturing source category and regulatory alternatives for the control of arsenic emissions are described in this chapter. Model furnaces are developed in order to provide estimates of the environmental, cost, and economic impacts of the regulatory alternatives on individual typical furnaces. The nationwide environmental, cost, and economic impacts which are presented in the subsequent chapters are based on the actual existing furnaces.

The model furnaces are based on data from the background information document (BID) for the glass manufacturing new source performance standard (NSPS)[1] except for the 4 and 23 Mg/day furnaces which were based on the actual plant data submitted by glass manufacturing companies.[2,3,4,5,6] It should be noted that in order to obtain conservative estimates for control costs, the gas flow data assumed in the NSPS analysis were on the high side. In addition, the gas flows estimated from actual plant data were based on very high stack oxygen level (18%). It is expected that due to energy conservation considerations, the actual gas flows and, therefore, the actual control costs may be somewhat lower. Section 4.1 presents the model furnaces in terms of production capacity, glass industry segment, stack parameters, and uncontrolled arsenic emissions. Section 4.2 describes the regulatory alternatives for control of arsenic emissions from glass plants.

4.1 MODEL FURNACES

The model furnaces for the glass manufacturing source category are defined to be various sizes of a single regenerative-type, fossil fuel-fired glass melting furnace with no add-on control device. The model furnace parameters are shown in Table 4-1. No specific glass type (e.g., lead, borosilicate, soda-lime, etc.) is assumed to be manufactured by the model furnaces. Instead, each model furnace is characterized as being in a

TABLE 4-1. GLASS MANUFACTURING MODEL FURNACE PARAMETERS

PRODUCTION CAPACITY Mg/day (tons/day) glass pulled	4.5 (5)	23 (25)	45 (50)	91 (100)	181 (200)	636 (700)
Glass industry segment	Pressed and blown	Pressed and blown	Pressed and blown	Pressed and blown	Pressed and blown, container, and wool fiberglass	Flat
Arsenic emissions, kg/hr (lb/hr)	0.046 (0.1)	0.24 (0.52)	0.47 (1.04)	0.95 (2.08)	1.89 (4.17)	6.63 (14.58)
Stack Height, m (ft)	25.9 (85)	25.9 (85)	25.9 (85)	25.9 (85)	25.9 (85)	25.9 (85)
Stack Diameter, m (ft)	0.4 (1.36)	0.89 (3.04)	1.0 (3.4)	1.4 (4.75)	2.1 (6.7)	4.4 (14.4)
Exit Temp., °K (°F)	480 (405)	480 (405)	480 (405)	480 (405)	480 (405)	480 (405)
Flow Rate, m^3/sec (acfm)	1.14 (2,400)	5.7 (12,000)	7.6 (16,000)	15.1 (32,000)	30.2 (64,000)	138.3 (293,000)
Flow Velocity, m/sec (fps)	9.1 (30)	9.1 (30)	9.1 (30)	9.1 (30)	9.1 (30)	9.1 (30)

general glass industry segment such as pressed and blown, container, etc. It should be noted that the glass type does not affect the flue gas flow rates from the furnaces. However, as shown in Table 2-2, the emission factors are affected by the type of glass produced. Since due to proprietary considerations, the model furnaces are not characterized as producing specific types of glasses, a mid-point emission factor of 0.25 kg/Mg glass pulled (0.5 lb/ton) is assumed for all model furnaces.

The stack parameters (gas temperature, stack height, stack diameter, gas flow rate, and gas flow velocity) are based on information from the NSPS background information document. Stack parameter information is used for the risk analysis presented in Appendix E. The risk analysis is performed for the actual existing furnaces and the actual stack parameters are used, when available. For furnaces with no stack parameter information, the model plant stack parameters were used. Table 4-2 presents the stack parameters used for the risk analysis.

4.2 REGULATORY ALTERNATIVES

The purpose of developing regulatory alternatives is to provide a basis for determining the air-quality and nonair-quality environmental impacts, energy requirements, and the costs associated with varying degrees of arsenic emissions reduction. The regulatory alternatives selected for analysis include "no NESHAP regulation" and two increasingly restrictive levels of control requirements. The two increasingly restrictive control requirements allow for analysis of the impacts of varying degrees of emissions reduction. The three regulatory alternatives are shown in Table 4-3 and are discussed below.

TABLE 4-2. STACK PARAMETERS USED FOR RISK ANALYSIS

Plant	Furnace	Stack Height M(Ft)	Stack Diameter M(Ft)	Vertical Cross-Sectional Area[a] M^2 (Ft^2)	Gas Velocity M/Sec (Ft/Sec)		Gas Temperature °K (°F)	
					Reg. Alt. 1	Reg. Alt. 2	Reg. Alt. 1	Reg. Alt. 2
1	A	22.3 (73)	1.52 (5)	750 (8,073)	14.0 (46)	14.0 (46)	505 (450)	505 (450)
	B	9.75 (32)	0.95 (3)	750 (8,073)	9.32 (31)	9.32 (31)	436 (325)	436 (325)
2	A	15.5 (50.7)	0.70 (2.3)	750 (8,073)	29.3 (96)	29.3 (96)	494 (430)	494 (430)
3	A	21.3 (70)	1.58 (5.2)	750 (8,073)	12.7 (41.6)	12.7 (41.6)	450 (350)	450 (350)
4	A	44.2 (145)	1.78 (5.8)	750 (8,073)	6.0 (19.8)	3.67 (12)	783 (950)	477 (400)
	B	36 (118)	1.4 (4.58)	750 (8,073)	10 (33)	6.6 (21.7)	725 (845)	477 (400)
	C	38.1 (125)	0.99 (3.25)	750 (8,073)	9.8 (32.2)	6.7 (22)	700 (800)	477 (400)
	D	19.2 (63)	0.8 (2.67)	750 (8,073)	18 (60)	13.7 (45.1)	636 (685)	477 (400)
	E	21.9 (72)	1.83 (6)	750 (8.073)	4.9 (16.1)	3.5 (11.5)	669 (745)	477 (400)
5	A	39.6 (130)	1.07 (3.5)	750 (8,073)	8.56 (28)	6.2 (20.4)	655 (720)	477 (400)
	B	29 (95)	1.52 (5)	750 (8,073)	3.0 (10)	2.4 (7.8)	610 (640)	477 (400)
6	A	15.2 (50)	2.4 (8)	750 (8,073)	3.1 (1.0)	10 (33)	310 (100)	477 (400)
	B	15.2 (50)	1.37 (4.5)	750 (8,073)	3.1 (10)	2.26 (7.4)	644 (700)	477 (400)
	C	36.6 (120)	1.52 (5)	750 (8,073)	6.2 (20.2)	4.2 (13.8)	700 (800)	477 (400)
7	A	18.3 (60)	0.91 (3)	750 (8,073)	7.6 (25)	7.6 (25)	410 (280)	410 (280)
8	A	41.1 (135)	1.8 (5.9)	750 (8,073)	3.0 (10)	3.0 (10)	440 (333)	440 (333)
9	A	41.1 (135)	2.4 (8.0)	750 (8,073)	3.4 (11)	2.6 (8.6)	666 (700)	477 (400)
10	A B C D Total From 4 Furnaces	15.2 (50)	4.98(16)	750 (8,073)	1.5 (5)	1.5 (5)	311 (100)	311 (100)
11	A	45.7 (150)	1.52 (5)	750 (8,073)	15.2 (50)	15.2 (50)	477 (400)	477 (400)
12	A (2 Stacks)	9.1 (30)	0.76 (2.5)	750 (8,073)	13.1 (43)		672 (750)	
		7.6 (25)	0.76 (2.5)	750 (8,073)	18.3 (60)		755 (900)	
		22.9 (75)[b]	0.91 (3.0)[a]	750 (8,073)		15.2 (50)		477 (400)
	B (2 Stacks)	15.2 (50)	0.82 (2.7)	750 (8,073)	29 (95)		644 (700)	
		9.1 (30)	0.76 (2.5)	750 (8,073)	18.6 (61)		544 (520)	
		22.9 (75)[b]	1.22 (4)[b]	750 (8,073)		15.2 (50)		477 (400)
	C	30.5 (100)	1.2 (4)	750 (8,073)	17.4 (57)	17.4 (57)	461 (370)	461 (370)
13	A B C D Common Stack	25.9 (85)	1.2 (4)	750 (8,073)	22.9 (75)	22.9 (75)	477 (400)	477 (400)
14	A	27.9 (90)	1.1 (3.7)	750 (8,073)	14.0 (46)	8.9 (29.1)	755 (900)	477 (400)
	B	27.9 (90)	1.2 (3.9)	750 (8,073)	15.2 (50)	15.2 (50)	477 (400)	477 (400)
15	A	29.0 (95)	0.45 (1.5)	750 (8,073)	12.2 (40)	12.2 (40)	644 (700)	644 (700)

[a] Vertical cross sectional area of the building perpendicular to the wind.

[b] Two stacks assumed to be replaced by single stack under Reg. Alt. 2.

TABLE 4-3. REGULATORY ALTERNATIVES FOR CONTROL OF INORGANIC ARSENIC EMISSIONS FROM GLASS MANUFACTURING

Regulatory Alternative 1:	No NESHAP regulation.
Regulatory Alternative 2:	Installation of electrostatic precipitators or fabric filters.
Regulatory Alternative 3:	Complete ban on inorganic arsenic emissions from glass melting furnaces.

4.2.1 Regulatory Alternative 1

Alternative 1 represents the general level of control that would exist in the absence of establishing any arsenic NESHAP regulations. None of the existing glass furnaces are currently required to control arsenic emissions at the Federal or State level. However, arsenic emissions from several existing glass furnaces are controlled indirectly as a result of State particulate matter regulations. The particulate matter regulations are met by installing an add-on control device, installing an electric boosting process modification, or collecting particulate matter as fallout in the furnace checkerwork. As shown in Table 2-2, 13 of the 32 existing arsenic emitting furnaces have add-on control devices (a fabric filter or an electrostatic precipitator).

4.2.2 Regulatory Alternative 2

This alternative represents the level of control achievable by installation of an electrostatic precipitator or a fabric filter.

4.2.3 Regulatory Alternative 3

This is the most restrictive alternative for control of arsenic emissions from glass furnaces. This alternative would require a complete elimination of arsenic emissions from glass furnaces.

4.3 REFERENCES

1. U. S. Environmental Protection Agency. Glass Manufacturing Background Information: Proposed Standards of Performance. Research Triangle Park, N. C. Publication No. EPA-450/3-79-005a. June 1979. pp. 6-8 to 6-14.

2. Letter from Armstrong, F. L., RCA Corporation, to Brooks, G., Radian Corporation. March 8, 1982. 1 p. Information on corrected estimate of arsenic emissions.

3. Letter from Goebel, G., Kentucky Bureau of Environmental Protection, to Brooks, G., Radian Corporation. February 11, 1982. 2 p. Information on inorganic arsenic emissions from Corning Glass Works plant in Danville.

4. Telecon. Iden, C., Owens-Illinois, with Brooks, G., Radian Corporation. March 3, 1982. Conversation about Owens-Illinois arsenic emissions.

5. Letter and attachments from Murray, D. E., Anchor Hocking Corporation, to Shareef, S. A., Radian Corporation. March 14, 1983. 5 p. Information on inorganic arsenic emissions from Anchor Hocking glass plants.

6. Letter and attachments from Cherill, J., Corning Glass Works, to Brooks, G., Radian Corporation. April 7, 1982. 19 p. Information on inorganic arsenic emissions from Corning Glass Works plants.

5.0 ENVIRONMENTAL IMPACT

The environmental impact resulting from the implementation of the three regulatory alternatives identified in Chapter 4 are discussed in this chapter. As discussed in Chapter 4, the impacts on model furnaces are presented for the purpose of providing estimates of the environmental impact on an individual furnace. The nationwide impacts are estimated by using the available emissions data for the existing furnaces shown in Table 2-5. Section 5.1 presents the air pollution impacts. The air emissions of arsenic from each model furnace are presented for the three regulatory alternatives. The total nationwide air emissions are based on the actual existing glass furnaces with available arsenic emissions data. Sections 5.2 through 5.4 present the water pollution, solid waste, and energy impacts.

5.1 AIR POLLUTION IMPACT

In this section the impact of each regulatory alternative on air pollution is considered. The impact of implementing the regulatory alternatives is calculated for each model furnace. The total nationwide impact is calculated for the actual furnaces.

5.1.1 Model Furnace Emissions

The arsenic emissions from each model furnace under the three regulatory alternatives are presented in Table 5-1. Under Regulatory Alternative 1, no NESHAP regulation, the arsenic emissions are the same as the baseline emissions presented in Chapter 4.

Regulatory Alternative 2 represents installation of a fabric filter or an electrostatic precipitator. As presented in Chapter 3, these devices have demonstrated reduction of arsenic emissions ranging from 90 to 99 percent. To be conservative, a reduction level of 90 percent is assumed for both fabric filters and electrostatic precipitators. The arsenic

TABLE 5-1. ARSENIC EMISSIONS FROM MODEL GLASS FURNACES UNDER THE THREE REGULATORY ALTERNATIVES

REGULATORY ALTERNATIVE	Arsenic Emissions, kg/hr (lb/hr)						Percent Reduction Over Baseline Arsenic Emissions[a]
	Model Furnace Mg/day (tons/day)						
	4.5 (5)	23 (25)	45 (250)	91 (100)	181 (200)	636 (700)	
1. No NESHAP regulation.	0.046 (0.1)	0.24 (0.52)	0.47 (1.04)	0.95 (2.08)	1.89 (4.17)	6.63 (14.58)	0
2. Installation of a fabric filter or an electrostatic precipitator.	0.0046 (0.01)	0.024 (0.052)	0.047 (0.104)	0.095 (0.208)	0.189 (0.417)	0.663 (1.458)	90
3. Complete ban on arsenic emissions from glass melting furnaces.	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	100

[a] Baseline is Regulatory Alternative 1.

emission levels shown for Regulatory Alternative 2, therefore, represent 90 percent reduction over baseline emissions.

Regulatory Alternative 3 requires complete elimination of arsenic emissions from glass melting furnaces. This would result in 100 percent reduction in arsenic emissions.

5.1.2 Nationwide Emissions

The total nationwide annual impact in the first year is calculated based on the available emissions data for arsenic emitting glass furnaces. As discussed in Chapter 2, there may be several other furnaces in the glass industry with arsenic emissions. Therefore, the total environmental impact is probably understated. Table 5-2 presents the nationwide arsenic emissions estimates for the first year under each regulatory alternative. The nationwide arsenic emissions under Regulatory Alternative 1 are the same as the baseline emissions presented in Table 2-2 and are about 36.7 Mg (40.5 tons). Emissions under Regulatory Alternative 2 are calculated based on installation of a fabric filter or an electrostatic precipitator on all existing furnaces that do not currently have add-on control devices. The arsenic control efficiency is assumed to be 90 percent. The nationwide emissions under Regulatory Alternative 2 are estimated to be 4.33 Mg (4.76 tons). This represents an annual emissions reduction of 32.37 Mg (35.61 tons) over baseline arsenic emissions.

Regulatory Alternative 3 would result in zero arsenic emissions. This represents a reduction of 36.7 Mg (40.5 tons) over Regulatory Alternative 1 and 4.33 Mg (4.76 tons) over Regulatory Alternative 2.

5.2 WATER POLLUTION IMPACT

There would be no water pollution impact due to implementation of any of the regulatory alternatives.

5.3 SOLID WASTE IMPACT

There would be no significant solid waste impact due to implementation of the regulatory alternatives. The catch from particulate control devices in glass plants are generally recycled to the batch feed.[1,2,3] One

TABLE 5-2. ESTIMATED FIRST YEAR NATIONWIDE ARSENIC EMISSIONS FROM GLASS FURNACES UNDER EACH REGULATORY ALTERNATIVE[a]

Plant	Furnace	Existing PM Controls that Reduce Arsenic Emissions[c]	Arsenic Emissions, Mg/yr (Tons/yr) Reg. Alt. 1	Reg. Alt. 2	Reg. Alt. 3
1	A	ESP preceded by evaporative cooler	0.027 (0.035)	0.027 (0.035)	-
	B	ESP preceded by evaporative cooler	0.006 (0.0056)	0.006 (0.0066)	-
2	A	ESP	0.069 (0.076)	0.069 (0.076)	-
3	A	ESP	0.089 (0.101)	0.089 (0.101)	-
4	A	None	3.09 (3.4)	0.309 (0.034)	-
	B	None	3.53 (3.9)	0.353 (0.39)	-
	C	None	0.73 (0.8)	0.073 (0.08)	-
	D	None	0.55 (0.6)	0.055 (0.06)	-
	E	None	0.55 (0.6)	0.055 (0.06)	-
5	A	None	1.27 (1.4)	0.127 (0.14)	-
	B	None	0.91 (1.0)	0.091 (0.1)	-
6	A	None	0.45 (0.5)	0.045 (0.05)	-
	B	None	1.82 (2.0)	0.182 (0.2)	-
	C	None	3.09 (3.4)	0.309 (0.34)	-
7	A	FF	0.19 (0.21)	0.19 (0.21)	-
8	A	ESP	0.076 (0.084)	0.076 (0.084)	-
9	A	EB	15.20 (16.8)	1.52 (1.68)	-
10	A B C D	Total from 4 furnaces None	0.038 (0.042)	0.0038 (0.0042)	-
11	A	ESP preceded by an evaporative cooler	0.023 (0.025)	0.023 (0.025)	-
12	A (2 stacks)	None	1.99 (2.19)	0.199 (0.219)	-
	B (2 stacks)	None	1.83 (2.01)	0.183 (0.201)	-
	C	ESP preceded by evaporative cooler and a cyclone	0.073 (0.08)	0.073 (0.08)	-

TABLE 5-2. (Continued)

Plant	Furnace	Existing PM Controls that Reduce Arsenic Emissions[c]	Arsenic Emissions, Mg/yr (Tons/yr) Reg. Alt. 1	Reg. Alt. 2	Reg. Alt. 3
13	A	Common Stack			
	B	ESP preceded by evaporative cooler	0.038 (0.042)	0.038 (0.042)	-
	C				
	D	ESP preceded by evaporative cooler	0.191 (0.21)	0.191 (0.21)	-
14	A	EB	0.76 (0.84)	0.076 (0.084)	-
	B	FF	0.038 (0.042)	0.038 (0.042)	-
15	A	None	0.118 (0.126)	0.0118 (0.0126)	-
		Total	36.70 (40.50)	4.33 (4.76)	0.0 (0.0)

[a] Emissions expressed as total elemental arsenic.

[b] FF = fabric filter
ESP = electrostatic precipitator
EB = electric boosting
PM = particulate matter

company reports that about 10 percent of the collected dust cannot be recycled and, therefore, must be disposed of.[4] This dust is classified as a hazardous waste.

5.4 ENERGY IMPACT

As in the case of the new source performance standard for the glass industry, the energy impact of the regulatory alternatives are not significant. Regulatory Alternative 1 will have no energy impact. There will be a minor negative energy impact under Regulatory Alternative 2. The energy required to operate fabric filters and electrostatic precipitators ranges from 0.006 to 0.03 kw-hr/kg of glass produced, depending upon the glass type. Using published values for the container glass, flat glass, and pressed and blown glass categories, the energy required to operate these control systems for these categories ranges from 0.2 to 2 percent, 0.2 percent, and from 0.1 to 0.5 percent of the energy needed to produce glass, respectively. As discussed in Chapter 2, it may not be technically feasible to substitute arsenic with other agents in the glasses that currently use arsenic. Therefore, it may be assumed that the production of all arsenic glasses will be eliminated under Regulatory Alternative 3, and, in the worst case, that existing furnaces that produce arsenic-containing glasses will close. Assuming that the 32 existing arsenic-using furnaces close, there will be a small positive energy inpact of about 580,000 Mw-hr per year, representing the energy saved by not operating these furnaces.

5.5 REFERENCES

1. Letter and attachments from Swander, T., RCA Corporation to Goodwin, D., EPA:ESED. September 27, 1978. 8 p. Information on arsenic in glass and arsenic emissions from glass manufacturing units.
2. Telecon. Iden, C., Owens-Illinois, with Brooks, G., Radian Corporation. March 3, 1982. Conversation about Owens-Illinois arsenic emissions.
3. Telecon. Biles, R., GTE, with Shareef, S. A., Radian Corporation. March 1, 1983. Conversation about inorganic arsenic emissions from GTE glass furnaces.
4. Draft trip report. S. A. Shareef, Radian Corporation, to file. March 8, 1983. 4 p. Report of March 2, 1983 visit to Corning Glass Works in Corning, New York.

6.0 COST ANALYSIS

This chapter presents a cost analysis of the regulatory alternatives described in Chapter 4. The cost impacts for individual model furnaces are estimated in Section 6.1. The nationwide cost impacts are estimated by calculating costs for the actual existing furnaces and are presented in Section 6.2.

6.1 COST ANALYSIS OF REGULATORY ALTERNATIVES FOR MODEL FURNACES

The three regulatory alternatives for controlling arsenic emissions from glass manufacturing furnaces were discussed in Chapter 4 and are listed again in Table 6-1.

TABLE 6-1. REGULATORY ALTERNATIVES FOR CONTROLLING ARSENIC EMISSIONS FROM GLASS MANUFACTURING FURNACES

Regulatory Alternative	Description
1	No NESHAP regulation.
2	Installation of electrostatic precipitators or fabric filters.
3	Complete ban on inorganic arsenic emissions from glass melting furnaces.

Regulatory Alternatives 1 and 3 have no capital costs associated with them and, thus, are not considered in this chapter. Costs associated with Regulatory Alternative 2 are presented in this section for the six model furnaces. The economic impacts of Regulatory Alternatives 2 and 3 are presented in Chapter 7.

6.1.1 Capital Costs

Installed capital costs of fabric filter and electrostatic precipitator (ESP) systems were estimated for each of the six model furnaces. The bases for the capital cost estimates are summarized in Table 6-2. The major components of the control system include the particulate device and an evaporative cooler (e.g., a spray chamber). The evaporative cooler is assumed to cool the gas from 207°C (405°F) to 121°C (250°F) in order to operate a cool side ESP or a baghouse.

For the fabric filter systems, costs of the control device, spray chamber, and other auxiliary equipment were determined from standard cost estimating references.[1,2] Equipment costs were updated to October 1982 dollars using Chemical Engineering Plant Cost Indices.[3,4] Additional capital costs for instruments and control and taxes and freight were based on a percentage of control device and auxiliary equipment costs.[5] Direct and indirect installation costs for the fabric filter systems were estimated as a factor of total purchased equipment costs.[6] Finally, in order to compute capital costs for existing furnaces, a retrofit allowance equivalent to 100 percent of installed capital costs was applied.

Capital cost estimates for ESP systems were based on the cost analysis of ESP systems performed in the background information document (BID) for New Source Performance Standards (NSPS) for the glass manufacturing industry.[7] In the NSPS cost analysis, the capital cost of the ESP systems was based on the purchase price of the control device and auxiliary equipment (except a spray chamber), the cost of site preparation, equipment installation, design engineering, the contractor's fee, and interest during construction. The cost components used in the NSPS document are shown in Table 6-3. Estimated costs were provided by glass manufacturers for actual retrofit installations and were based on the use of heavy-duty equipment, liberal installation allowances, and 20 percent contingency. Not included are costs of research and development, cost of land, possible loss of production during equipment installation, or losses during startup. Equipment cost of ESP's was based on estimates relating plate area to cost for conventional plate and wire precipitators. Installation costs and

TABLE 6-2. BASES FOR CAPITAL COST ESTIMATES

Capital Cost Item	Cost Basis	Reference
Fabric Filter System		
Fabric Filter	Air-to-cloth ratio = 0.61 $m^3/min/m^2$ (2 cfm/ft^2). Filtering media - Nomex. Reverse air cleaning, continuous duty, suction blower, insulated. Net cloth area = inlet flow ÷ air-to-cloth ratio. Baghouse costs based on net cloth area. Filter costs based on gross cloth area.	Ref. 1, Fig. 5-13 Table 5.1 Table 5.2
Spray Chamber	Inlet gas temperature = 207°C (405°F). Outlet gas temperature = 121°C (250°F). Water temperature = 16°C (60°F). Inlet flow rate is the furnace outlet flow rate. Outlet flow rate is equivalent to the inlet flow rate plus the volume of added water vapor. Spray chamber costs based on inlet flow rate.	Ref. 1, Fig. 4-23
Suction Blower	Gas temperature = 121°C (250°F). Actual ΔP = 25.4 cm (10 in.) H_2O. ΔP at standard conditions = 34 cm (13.4 in.) H_2O. Flow rate is the fabric filter outlet flow rate. Backwardly curved fan costs based on ΔP at standard conditions and flow rate.	Ref. 1, Fig. 4-33
Pump	Spray chamber water requirements = 0.024 ℓ/m^3 (1.8 x 10^{-4} gal/ft^3) of gas through spray chamber. Pump costs based on water requirements.	Ref. 2, 100-300
Motors	Totally enclosed motor costs based on RPM and horsepower requirements for fan and pump operation.	Ref. 1, Fig. 4-34 Table 4.8 Ref. 2, 100-651
Ductwork, Expansion Joints, and Dampers	Duct length = 30.5 m (100 ft) per fan. Duct diameter = spray chamber outlet flow rate ÷ 1,372 m/min (4,500 fpm) (minimum velocity to prevent fallout). Duct material - 0.635 cm (0.25 in.) carbon steel. Two expansion joints per fan. Two circular dampers per fan.	Ref. 1, Fig. 4-7 Fig. 4-12 Fig. 4-14
Screw Conveyor	Screw conveyor required on model plants > 91 Mg/day (100 tons/day). Conveyor length = 15 m (50 ft). Screw diameter = 23 cm (9 in.) for model plants < 181 Mg/day (200 tons/day). Screw diameter = 30 cm (12 in.) for 635 Mg/day (700 tons/day) model plant.	Ref. 1, Fig. 4-25 Ref. 3, p. 8-65
Instruments and Control	10 percent of fabric filter, spray chamber, and auxiliary equipment costs.	Ref. 1, Table 3.3
Taxes and Freight	8 percent of fabric filter, spray chamber, and auxiliary equipment costs.	Ref. 1, Table 3.3
Direct and Indirect Installation Costs	117 percent of purchased equipment costs.	Ref. 1, Table 3.3
Retrofit Allowance	100 percent of installed capital costs.	
Electrostatic Precipitator System		
Installed costs for control device and auxiliary equipment (except spray chamber)	Installed costs for control device and auxiliary equipment (except spray chamber) based on cost estimates presented in the background information document for NSPS for the glass manufacturing industry. Specific collection area = 3.28 m^2 per m^3/min (1,000 ft^2/1,000 ACFM) for pressed and blown and wool fiberglass furnaces, 1.08 m^2 per m^3/min (330 ft^2/1,000 acfm) for flat glass furnaces and 1.31 m^2 per m^3/min (400 ft^2/1,000 acfm) for container glass furnaces. Installed costs follow log/log relationship with the following data points: 279 m^2 (3,000 ft^2) precipitator - $815,405 5,574 m^2 (60,000 ft^2) precipitator - $3,973,915	Ref. 7, Fig. 8-3
Spray Chamber	Same as spray chamber cost estimates developed for fabric filter systems.	Ref. 1, Fig. 4-23

TABLE 6-3. COMPONENT OF CAPITAL COSTS FOR ELECTROSTATIC PRECIPITATORS

DIRECT COST COMPONENTS[a]

- Equipment
- Instrumentation
- Piping
- Electrical
- Foundation
- Structural
- Sitework
- Insulation
- Paintings
- Buildings

INDIRECT COST COMPONENTS[a]

- Field overhead
- Contractor's fee
- Engineering
- Freight
- Offsite
- Taxes (5% of material)
- Allowable for shakedown
- Spares
- Contingency (20% of total)
- Interest during construction

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[a] Each component cost estimated separately depending on equipment involved.

indirect costs were based on published information and engineering judgment. Total installed costs calculated in this manner for ESP systems are shown in Figure 6-1. Figure 6-1 also shows actual control system costs as reported by industry in response to EPA inquiries for the NSPS study. It can be seen from Figure 6-1 that the relationship between cost and the size of the ESP system follows an increasing logarithmic relationship such that a doubling of plate area results in a cost increase of about 1.5 times. For purpose of this analysis, the NSPS cost estimates were updated to October 1982 dollars using Chemical Engineering Plant Indices and the installed cost of a spray chamber was added.[8,9,10]

Table 6-4 presents the installed capital costs of fabric filter and ESP systems for the six model furnaces.

6.1.2 Annualized Costs

Total annualized costs for fabric filter and ESP systems include direct operating costs and capital recovery costs. The bases used in determining annualized costs for the six model furnaces using fabric filter and ESP systems are summarized in Table 6-5. Direct operating costs include operating labor, maintenance, overhead, replacement materials, utilities, waste disposal, property taxes, insurance, and administration.

The number of operator man-hours required for ESP systems was estimated for the six model furnaces using the following equation:

$$\text{man-hours/yr} = 485 \ln x - 1{,}221 \text{ (Ref. 11)}$$

where: x = kg/day of dust collected = 4.75 x glass production, Mg/day

The equation was derived such that operator man-hour requirements determined for the smallest and largest model furnaces would represent the range of values recommended for ESP systems in Reference 1.[12] Operator man-hours for fabric filter systems were estimated to be double the requirements for ESP systems for the individual model furnaces.[13] Maintenance labor costs were based on estimated maintenance man-hour requirements on a per-shift basis. Maintenance requirements were estimated to be one man-hour per shift for fabric filter systems and 0.5 man-hour per shift for ESP systems.[14]

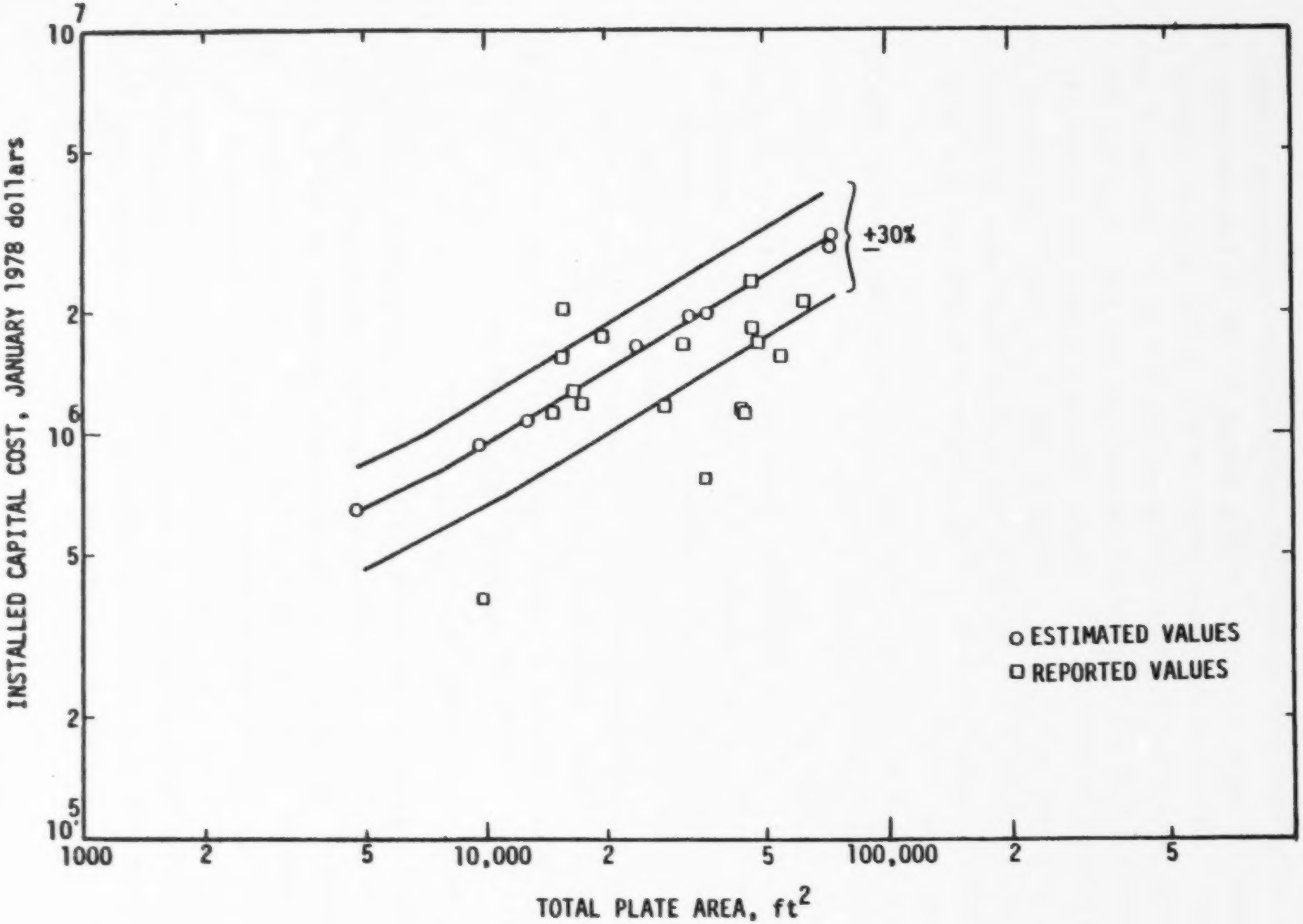

Figure 6-1. Reported installed costs of electrostatic precipitator control systems compared with estimated cost curve used in this study.

TABLE 6-4. CAPITAL COST ESTIMATES FOR MODEL FURNACES
(Thousands of October 1982 Dollars)

Capital Cost Item	Model Furnace Size, Mg/day (Tons/day) 4.5 (5)	 23 (25)	 45 (50)	 91 (100)	 181 (200)	 636 (700)
Fabric Filter System						
Fabric filter	65.9	104	120	179	296	1,148
Spray chamber	62.7	65.9	67.3	72.7	83.5	161
Auxiliary equipment	12.0	25.5	22.7	37.3	56.3	175
Instruments and control	14.1	19.5	21.0	28.9	43.6	148
Taxes and freight	11.2	15.6	16.8	23.1	34.9	119
Direct and indirect installation costs	194	269	290	399	602	2,049
Installed Capital Costs	360	500	538	740	1,116	3,800
Retrofit Allowance	360	500	538	740	1,116	3,800
Total Installed Capital Costs	720	1,000	1,076	1,480	2,232	7,600
Electrostatic Precipitator System						
Total Installed Capital Costs	666	1,530	1,813	2,615	3,772 (pressed and blown and wool fiberglass furnaces) 2,335 (container glass furnaces)	4,751

TABLE 6-5. BASES FOR ANNUALIZED COSTS

	Cost Basis	
Annualized Cost Item	Fabric Filter	Electrostatic Precipitator
Operating Labor		
(a) operator	hrs/yr = 2 (485 lnx - 1,221) where x = kg/day of dust collected and kg dust collected/Mg of glass = 4.75 (9.5 lb/ton). $11.38/hr Bureau of Labor Statistics (BLS) average wage plus 20 percent fringes for glass industry workers	hrs/yr = 485 lnx - 1.221 @ $11.38/hr
(b) supervisor	15 percent of operator cost	15 percent of operator cost
Maintenance		
(a) labor	1 hr/shift, $12.52/hr (hourly rate of 10 percent premium over operating labor)	0.5 hr/shift, $12.52/hr
(b) materials	100 percent of maintenance labor cost	100 percent of maintenance labor cost
Overhead	80 percent of labor charges for operation and maintenance	80 percent of labor charges for operation and maintenance
Replacement Parts		
(a) materials	Cost of bags/useful life of 1.5 yrs	NA
(b) labor	100 percent of replacement materials cost	
Utilities		
(a) electricity	$0.0525/kWh	$0.0525/kWh
(b) water	$0.066/l ($0.25/1,000 gal)	$0.066/l ($0.25/1,000 gal)
Waste Disposal	$44/Mg ($40/ton) kg dust collected/Mg of glass = 4.75 (9.5 lb/ton)	$44/Mg ($40/ton) kg dust collected/Mg of glass = 4.75 (9.5 lb/ton)
Property Tax, Insurance and Administration	4 percent of installed capital cost	4 percent of installed capital cost
Capital Recovery	10 percent interest over 20 year equipment life (CRF = 11.746 percent of installed capital cost)	10 percent interest over 20 year equipment life (CRF = 11.746 percent of installed capital cost)

NA = Not applicable.

Overhead costs were based on a factor of total labor charges for operation and maintenance.[15]

Replacement parts for fabric filter systems consist of filter bags. The annualized cost of replacing fabric filter bags is determined by dividing the purchased cost of the bags by their estimated useful life of 1.5 years.[16] Labor costs associated with replacement of fabric filter bags were based on 100 percent of replacement materials cost.[17]

Utility requirements for the fabric filter and spray cooler systems include electricity for fan, pump, and reverse air cleaning operations and water for the spray chamber. Electricity requirements for fabric filters were estimated from the appropriate equations and charts presented in the standard cost estimating references.[18] ESP systems require electricity to meet precipitator power requirements of 10.76 watts/m^2 (1,000 watts/1,000 ft^2) of precipitator and additional fan power requirements.[19] Waste disposal costs were based on estimated disposal requirements of 4.75 kg dust/Mg of glass produced. Although the amount of waste disposed of is expected to be 0 to 10 percent of the dust collected, it is conservatively assumed that all dust is disposed of in an offsite landfill. Property taxes, insurance, and administration costs were estimated as a factor of total installed capital costs.[20]

Capital recovery costs were based on 10 percent interest over 20 year equipment life for both fabric filter and ESP systems. The capital recovery factor (CRF) is calculated using the following equation:

$$CRF = \frac{i\,(1 + i)^n}{(1 + i)^n - 1}$$

where: i = annual interest rate
n = equipment life (years)

Table 6-6 presents annualized costs for fabric filter and ESP systems for the six model plants.

TABLE 6-6. ANNUALIZED COSTS FOR MODEL FURNACES[a]
(Thousands of October 1982 Dollars)

Annualized Cost Item	Model Plant Size, Mg/day (Tons/day) 4.5 (5)	23 (25)	45 (50)	91 (100)	181 (200)	636 (700)
Fabric Filter System						
Operating labor	6.99	27.4	36.2	45.0	53.8	69.7
Maintenance	26.3	26.3	26.3	26.3	26.3	26.3
Overhead	16.1	32.5	39.5	46.5	53.6	66.3
Replacement parts	4.15	15.6	20.8	34.6	64.7	268
Utilities	2.93	12.5	14.9	28.0	53.7	265
Waste disposal	0.33	1.66	3.32	6.64	13.3	46.6
Property tax, insurance, and administration	28.8	40.0	43.0	59.1	89.3	304
Capital recovery (10% interest, 20 year life, CRF = 0.1176)	84.5	117	126	174	262	893
Total Annualized Costs	170	273	310	420	617	1,939
Electrostatic Precipitator System						
Operating labor	4.02	13.7	18.1	22.5	26.9[b] 26.9[c]	34.9
Maintenance	13.1	13.1	13.1	13.1	13.1[b] 13.1[c]	13.1
Overhead	8.47	16.2	19.8	23.3	26.8[b] 26.8[c]	33.2
Utilities	1.24	6.00	8.29	16.6	33.1[b] 18.9[c]	78.9
Waste disposal	0.33	1.66	3.32	6.6	13.3[b] 13.3[c]	46.6
Property tax, insurance, and administration	26.6	61.2	72.5	105	151.0[b] 93.4[c]	190
Capital recovery (10% interest, 20 year life, CRF = 0.11746)	78.2	180	213	307	443[b] 274[c]	558
Total Annualized Costs	132	292	348	494	707[b] 467[c]	955

[a] Based on 8,400 operating hours/yr.

[b] Pressed and blown and wool fiberglass furnaces.

[c] Container glass furnaces.

6.2 NATIONWIDE COST IMPACTS

The nationwide cost impacts are estimated for the actual existing arsenic emitting furnaces without add-on particulate devices listed in Table 3-5. The capital costs are for electrostatic precipitator systems and are calculated for the actual gas flows from the existing glass furnaces. The cost bases used are the same as presented for electrostatic precipitators in Tables 6-2 and 6-5. The nationwide capital cost estimates, the first year annualized costs, and the first year arsenic emission reductions are presented in Table 6-7.

TABLE 6-7. NATIONWIDE FIRST YEAR COST IMPACTS
(Last Quarter 1982 Dollars)

Capital Costs (Million dollars)	29.84
Annualized Costs (Million dollars)	5.39
Emission Reductions (Mg)	32.37

6.3 OTHER COST CONSIDERATIONS

6.3.1 Costs Associated with Monitoring

The costs associated with monitoring include costs for continuous opacity monitoring devices. Capital and annualized costs for continuous opacity monitoring include equipment and installation costs for a transmissometer, recorder, and other associated equipment and are estimated to be about $25,000 per site. Annualized costs include preventative maintenance, calibration, recording and reducing data, general maintenance and capital recovery and are estimated to be about $14,000 per source.[21]

6.4 REFERENCES

1. Neveril, R. B. (GARD, Incorporated.) Capital and Operating Costs of Selected Air Pollution Control Systems. (Prepared for the U. S. Environmental Protection Agency.) Research Triangle Park, N. C. Publication No. EPA-450/5-80-002. December 1978.

2. Richardson Engineering Services, Inc. Process Plant Construction Estimating Standards, Volume 4. San Marcos, California, 1982. Work account pp. 100-300 and 100-651.

3. Economic Indicators. Chemical Engineering. 90(3):7. February 7, 1983.

4. Reference 1, Table 3.1.

5. Reference 1, Table 3.3.

6. Reference 5.

7. U. S. Environmental Protection Agency. Glass Manufacturing Background Information: Proposed Standards of Performance. Research Triangle Park, N. C. Publication No. EPA-450/3-79-005a. June 1979. pp. 8-52 to 8-62.

8. Reference 3.

9. Reference 4.

10. Reference 1, Figure 4-23.

11. Letter and attachments from Myers, R. E., EPA:ISB to Jenkins, R., EPA:EAB. December 7, 1981. 2 p. Revising annual control costs for glass manufacturing plants.

12. Reference 1, Table 3.5.

13. Reference 11.

14. Reference 12.

15. Reference 1, Table 3.4.

16. Reference 1, Table 3.6.

17. Reference 15.

18. Reference 1, p. 3-17.

19. Letter and attachments from Myers, R. E., EPA:ISB, to file. April 21, 1983. Model furnace control cost for ESP systems.

20. Reference 15.

21. Memo from Fidler, K., Radian Corporation, to file. March 30, 1983. 2 p. Updated costs of opacity monitoring.

7.0 ECONOMIC IMPACT

This chapter first presents an economic profile of the glass industry (Section 7.1). The data presented in the economic profile is then used in an analysis of the economic impacts of alternatives to regulating inorganic arsenic from the industry (Sections 7.2 and 7.3). The economic profile focuses on several glass industry characteristics, such as: number and location of plants, glass supply, glass demand, prices, value of shipments, competition, and employment.

7.1 Industry Economic Profile

7.1.1 Introduction

Four major segments of the glass industry are included in this profile: (1) pressed and blown glass not elsewhere classified, which is Standard Industrial Classification (SIC) 3229; (2) flat glass, which is SIC 3211; (3) container glass, which is SIC 3221; and (4) wool fiberglass, which is part of SIC 3296 (Mineral Wool).[1]

The products of these industries are briefly discussed. Pressed and blown glassware includes textile fiberglass (a fiberglass reinforced plastic used primarily in automobiles) and the following other industries: (1) machine-made consumer pressed and blown glassware (tumblers, stemware, and tableware); (2) handmade consumer pressed and blown glassware; (3) glass tubing for fluorescent and neon lighting, (4) incandescent light bulb blanks; (5) television picture tube envelopes; (6) scientific and technical glass; and (7) optical glass. Major attention is given to these seven industries in the pressed and blown category. Flat glass is basically window glass and is used in the construction and automobile industries. Container glass is bottles. Wool fiberglass is primarily used in the thermal insulation of residential and nonresidential structures.

Table 7-1 summarizes the value of shipments in the four segments of the glass industry in 1980, and Table 7-2 summarizes the number of companies and employment in the same industries. From the first table, it can be seen that these four industries together accounted for 0.4 percent of GNP in 1980.

Table 7-1

VALUE OF SHIPMENTS IN THE GLASS INDUSTRY, 1980[2,3]

SIC Code	Industry	Value of Shipments (million dollars)	Value of Shipments as percent of GNP
3229[a]	Pressed and Blown Glass not elsewhere classified	2,847.5	.108
3211	Flat Glass	1,497.6	.057
3221	Container Glass	4,486.3	.170
Part of 3296[b]	Wool Fiberglass	1,340.6	.051
TOTAL		10,172.0	.386

[a] Includes textile fiberglass shipments of 681.0 million dollars.

[b] Wool fiberglass accounts for 63 percent of SIC 3296, Mineral Wool. SIC 3296 had a value of shipments of 2,128.0.

Table 7-2

NUMBER OF COMPANIES AND EMPLOYMENT IN THE GLASS INDUSTRY, 1980[4-6]

SIC Code	Industry	Number of Companies[a]	Total Employment (1,000)	Employment of Production Workers (1,000)
3229[b]	Pressed and Blown Glass not elsewhere classified	325	45.7	37.1
3211	Flat Glass	43	17.3	13.8
3221	Container Glass	31	64.5	56.5
Part of 3296[c]	Wool Fiberglass	4	13.9	11.2
	TOTAL	403	141.4	118.6

[a] Data on the number of companies is from 1977.

[b] Includes textile fiberglass for which no separate figures are reported for employment.

[c] Wool fiberglass accounts for 63 percent of SIC 3296, Mineral Wool. SIC 3296 had a total employment of 22,000 and employed 17,700 production workers in 1980.

Five firms in SIC 3229 which have been identified by EPA as using arsenic in glass melting furnaces at 15 plants are of principal interest for the purpose of the impact analysis in Section 7.2. The five firms are Anchor Hocking, Corning Glass Works, GTE, Owens-Illinois, and RCA.[7] The plants and products are in Table 7-3. SIC 3211 and SIC 3221 are included in this profile because they have used arsenic in the past and/or may elect to do so in the future. Textile fiberglass (part of SIC 3229) and wool fiberglass (part of SIC 3296) are not known to contain arsenic. Therefore they will not be discussed in this chapter.

Table 9-4 summarizes the value of shipments for the seven industries in SIC 3229 that have been identified as of principal interest. As this table shows, there were marked differences in the growth in value of shipments. Glass for fluorescent lighting, for machine-made pressed and blown glassware, and for scientific purposes (including opthalmic lens blanks) grew more than 10 percent per year between 1970 and 1981. Handmade pressed and blown glass, on the other hand, grew only 5.6 percent per year.

When it is used in glass manufacturing, arsenic performs several functions. Its major functions are to prevent the formation of bubbles and to act as a decolorizing agent. It is also used in some instances in special glass types to impart other particular properties needed for the end use of the glass. For example, arsenic can provide stable fixation of certain colors for optical glass by stabilizing selenium, provide high glass permeability to infrared light for camera lenses, and provide a high degree of energy transmission for solar collector glass.[8]

The basic raw materials for most glass production include sand in the form of silica dioxide, soda ash, and limestone. Additional materials such as boric acid are added to the basic raw materials to obtain a variety of glass types, such as borosilicate glass or lead crystal. The raw materials for glass production are relatively abundant so that none is in short supply.[9]

7.1.2 Machine-Made Pressed And Blown Consumer Glassware

7.1.2.1 Introduction. In 1979 there were seven major firms who produced machine-pressed and blown consumerware in 13 plants in 7 states of the United States. Four plants were located in the Central part of the country, one on the West Coast, and eight in the Eastern Sector. There were

Table 7-3

GLASS MANUFACTURING PLANTS WHICH ADD ARSENIC TO RAW MATERIALS[10-14]

Plant	Furnace	Primary Products[a]
1	A-B	TV Picture Tube Components
2	A	Glass Tubing
3	A	TV Picture Tube Components
4	A-E	Tableware Glass
5	A-B	Specialty Container
6	A-C	Tableware Glass
7	A	Heat Resistant Globes, Electric Light Covers
8	A	Lead Glasses
9	A	Tableware Glass
10	A-D	Optical Glasses
11	A	TV Picture Tube Components
12	A-C	Tableware Glass
13	A-D	Scientific and Technical Glass Tubing
14	A-B	Aluminosilicate and Lead Glasses, Scientific Glassware
15	A	Hand Blown Lead Crystal Glass

[a] All products are machine-made except where noted

Table 7-4

SHIPMENTS OF CONSUMER, SCIENTIFIC, TECHNICAL, AND INDUSTRIAL GLASSWARE, 1970 TO 1981[15-24]

(Thousands of Dollars)

SIC Code	Product Description	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	Annual Compound Growth Rates	
														1970-1981	1975-1981
3229121 to 3229128	Machine-made pressed and blown glassware	286,749	326,291	380,022	418,674	462,408	625,664	554,085	686,581	732,399	758,399	808,605	912,700	11.1	8.7
3229131 to 3229133	Handmade pressed and blown glassware	31,450	32,577	36,502	37,980	40,126	38,046	36,863	42,890	46,662	47,696	55,125	56,992	5.6	7.5
3229227	Tubing and cane for fluorescent and neon lighting	37,744	38,481	40,151	45,386	42,958	50,102	40,608	56,630	65,952	84,811	103,607	109,195	10.1	17.9
3229225 and 3229235	Incandescent electric bulb blanks and television tube blanks	214,136	211,752	268,399	295,922	235,000	298,163	236,377	311,085	333,103	372,655	426,815	441,284	6.8	11.0
3229423 to 3229427	Scientific, laboratory, industrial and technical glassware; ophthalmic lens blanks and optical instrument lens blanks	156,424	170,116	D[b]	D[b]	260,480	270,293	246,455	295,168	353,233	401,279	438,500	476,235	10.7	11.6
	All other[c]	183,888	198,470	428,833	491,410	257,536	314,375	256,238	438,829	523,750	587,677	686,571	732,868	13.4	19.1
	TOTAL	910,391	977,687	1,153,907	1,289,372	1,298,508	1,596,643	1,370,626	1,831,183	2,055,099	2,252,517	2,519,223	2,729,274	10.5	12.2

[a] Compound growth rates are calculated using two equations:
(1) $G = (X_n/X_1)^{1/n}$
where G = compound growth multiplier; X_n = the value of X in the time period n; X_1 = the value of X in time period 1; n = the length of time period; and
(2) The compound growth rate (C) can be found by: $C = G - 1$.

[b] D = withheld to avoid disclosing figures of individual companies.

[c] Includes substantial interplant transfers of partially fabricated products.

also fourteen plants that are primarily in the hand-pressed and blown sector but which have been identified as having machine-pressed and blown capabilities.[25]

7.1.2.2 Market Concentration. The sector is highly concentrated. Currently, seven firms predominate: Corning Glass, Owens-Illinois, Anchor Hocking, Brockway, Bartlett-Collins, Jeanette Corp., and J. G. Durand International, Inc.[26]

7.1.2.3 Supply. The most noteworthy aspect of supply in this industry is that imports from a large number of foreign countries play a substantial role in domestic supply. Table and kitchenware represent the largest category of imports in this category of the pressed and blown segment of the glass industry.[26]

7.1.2.4 Demand. In this sector, consumer taste and relative price between similar items are the major determinants of demand. Corning Glass and Anchor Hocking produce large lines of similar heat-resistant table and kitchenware. Owens-Illinois and Anchor Hocking produce similar tumbler and stemware items. Brand loyalty plays a large part in which firm's products are chosen by the consumer.[27]

The availability of a wide variety of substitutes from the import market, especially in the tableware, tumbler, and stemware categories, provides a highly competitive structure in this sector. The impact of plastics and paper tableware products cannot be assessed.[27]

Table 7-5 summarizes output, shipments and price for machine-made consumer glassware between 1970 and 1981. As this table shows, output (in 1,000 dozen) for tumblers and stemware declined at an average compound rate of 1.5 percent between 1970 and 1981; output of tableware and cookware during the same period of time grew 1.5 percent a year. Both sectors have experienced declines in 1980 and 1981 due to the recession.

Value of shipments rose throughout the same time period. This is because prices rose at a substantial rate.

7.1.2.5 Prices. Prices for tumblers and stemware are typically measured as prices per 1,000 dozen, and prices for tableware and cookware are

Table 7-5

SHIPMENTS, OUTPUT AND PRICES OF MACHINE-MADE CONSUMER GLASSWARE, 1970 TO 1981[15-24]

	Tumblers and Stemware			Tableware and Cookware		
	Output 1,000 Dozen	Shipments $1,000	Price Per 1,000 Dozen	Output 1,000 Pieces	Shipments $1,000	Price Per 1,000 Pieces
1970	84,819	121,966	1,438	324,852	131,051	403
1971	91,660	135,619	1,480	395,884	151,914	384
1972	92,308	156,543	1,696	430,270	176,800	411
1973	82,908	156,229	1,884	458,498	208,394	455
1974	78,649	164,375	2,090	466,455	235,689	505
1975	87,277	206,885	2,370	474,668	278,704	587
1976	93,405	239,825	2,568	494,533	312,067	631
1977	90,898	245,383	2,700	504,965	355,595	704
1978	86,112	256,735	2,981	523,542	382,484	731
1979	75,160	259,206	3,449	519,047	402,942	776
1980	68,084	286,869	4,213	377,000	415,456	1,102
1981	72,172	325,433	4,509	381,156	473,033	1,241
Annual Compound Growth Rates						
1970-1981	-1.5	9.3	10.9	1.5	12.4	10.8
1975-1981	-3.1	7.8	11.3	-3.6	9.2	13.3

typically measured as prices per 1,000 pieces. As Table 7-5 shows, the price of tumblers and stemware per 1,000 dozen in 1981 was $4,509. The price of tableware and cookware in the same year was $1,241 per 1,000 pieces. Assuming that one pound of glass is required to produce between 2 and 6 pieces of tumblers and stemware, the price per unit weight would be between $1.65/kg and $4.96/kg ($0.75/lb and $2.25/lb). Assuming that tableware and cookware require production of between 1 and 4 lb each, the price per unit weight would be between $2.76/kg and $11.02/kg ($1.25/lb and $5.00/lb).

Obviously it is difficult to obtain an estimate of the price per unit weight of all machine-made pressed and blown consumer glassware. In August, 1978, an industry source estimated it to be $3.218/kg ($1.46/lb).[28] This estimate can be updated to October, 1982, using an average of the producer price indexes for flat glass and container glass.[29] This results in an estimate of $4.386/kg ($1.99/lb) for October, 1982.

7.1.3 Handmade Pressed And Blown Glassware

7.1.3.1 Introduction. In 1979 there were 84 firms that were identified as producing handmade pressed and blown products in 90 plants in 17 states. The greatest concentration of plants is located in the Ohio-Pennsylvania-West Virginia area where 53 of the participating plants are located. West Virginia has 28 firms producing in 30 plants.[30] Currently, it is estimated there are 80 firms, 30 of which are in the handmade pressed sector and 50 in the handmade blown sector.[31]

7.1.3.2 Market Concentration. There is little apparent concentration in this industry. Many of the firms participating in this sector are small and privately owned, producing in one plant only.[30] About half of the firms in this industry are estimated to have less than 100 employees.[31]

Manufacturers own their own molds and select their own designs or patterns. In the past, customers placed special orders, and products were made to order. The more recent trend is toward annual contract production. The sector is characterized by entreprenuership.[32]

7.1.3.3 Supply. The major aspect of supply in this industry is the role of imports. Imports are typically large and have grown in recent years.[32]

7.1.3.4 Demand. Hand-pressed and blown glassware supplies that portion of the market that demands uniqueness and craftmanship. Because large capital investment in machines and in multiple molds is not justified in this sector, the volume of production and the variety of items produced are low. Products are valued by the consumer because they are in relatively short supply and because of the quality of individual craftsmanship which is attached to them.[33]

Although machine-pressed and blown products are not perfect substitutes for hand-processed items, both machine-made products and imported hand-processed items are partial substitutes for U.S. hand-blown glassware.[31] (Plastics have made some impact on the novelty glass portion of the market. To the extent that uniqueness and the value of craftsmanship determine demand for hand-processed products, plastics are not perfect substitutes.)[33]

Hand-pressed and blown products represent luxury spending from personal disposable income. They may represent major expenditures. In periods of economic uncertainty, consumers may defer purchases of these items or may purchase a lower-cost, though imperfect, substitute. Demand appears to be highly price-elastic.[33]

Table 7-6 summarizes output, value of shipments, and prices for hand-made consumer glassware. As the data in this table shows, output of tumblers and tableware has declined 7.3 percent per year between 1970 and 1981. Output of stemware declined 4.2 percent during the same period of time. It should be noted that stemware output has declined 14.8 percent per year since 1975 and that this segment has been particularly hard-hit by the current recession. The current level of capacity utilization in this industry is said to be only 50 percent.[31]

7.1.3.5 Prices. Prices of handmade tumblers and tableware are typically measured as price per 1,000 pieces, and prices of stemware are measured as prices per 1,000 dozen. As Table 7-6 shows, the price of hand-made tumblers and tableware in 1981 was $3,270 per 1,000 pieces, and the price of handmade stemware in the same year was $30,092 per 1,000 dozen. the same problem exists here as with machine-made pressed and blown products in arriving at a price per unit weight.

In 1978, EPA used an estimated price of $6.061/kg ($2.75/lb).[34] Using the producer price index for container and flat glass, this figure can be used to arrive at an estimate for October, 1982. The October, 1982, estimated price for all hand-made glassware is $8.419/kg ($3.82/lb).

Table 7-6

SHIPMENTS, OUTPUT AND PRICES OF HANDMADE CONSUMER GLASSWARE, 1970 TO 1981[15-24]

	Tumblers and Tableware			Stemware		
	Output 1,000 Pieces	Shipments $1,000	Price Per 1,000 Pieces	Output 1,000 Dozen	Shipments $1,000	Price Per 1,000 Dozen
1970	18,510	16,180	874	1,641	15,270	9,305
1971	17,189	15,817	920	1,927	16,760	8,697
1972	18,457	17,582	953	2,069	18,920	9,145
1973	16,875	16,083	953	3,094	21,897	7,077
1974	15,507	19,010	1,226	2,897	21,116	7,289
1975	11,194	17,059	1,524	2,666	19,804	7,428
1976	8,963	17,527	1,955	2,756	20,519	7,445
1977	8,330	18,732	2,249	2,017	24,158	11,977
1978	9,010	20,681	2,295	2,088	25,981	12,443
1979	9,073	21,486	2,368	2,326	26,210	11,268
1980	7,906	24,252	3,068	966	30,873	31,960
1981	8,061	26,358	3,270	1,018	30,634	30,092
Annual Compound Growth Rates						
1970-1981	-7.3	4.5	12.7	-4.2	6.5	11.3
1975-1981	-5.3	7.5	13.6	-14.8	7.5	26.3

7.1.4 Glass Tubing For Fluorescent And Neon Lighting

7.1.4.1 Introduction. There are currently only three firms that manufacture glass tubing for fluorescent and neon lighting.[35]

7.1.4.2 Market Concentration. This industry is highly concentrated. The three firms are: General Electric, GTE Sylvania, and North American Phillips.[35] These firms produce multi-product lines and are integrated in areas other than glass production as well.[36]

Investment capital requirements for equipment in this category is so large, as is volume demanded, that small flourescent and neon light manufacturers find it more economically feasible to buy from a large firm than to produce glass tubing themselves. The major producers are large multi-product firms, and light tubing manufacture does not account for a significant portion of their sales volume.[36]

7.1.4.3 Supply. A high percentage of the output of this industry is used captively by the firms that produce glass tubing. Neither imports nor exports appear to influence the domestic market for this tubing.[37]

7.1.4.4 Demand. Fluorescent and neon lights are the end-products. Demand for the product is largely from the non-residential lighting market and is determined by the need for the product. Nothing substitutes for glass in lighting, and as a result demand appears to be relatively price-inelastic.[37]

The demand for fluorescent lighting does, however, depend on the state of the economy, because plants which are shut down (or only partially used) do not need to replace lights. As a result, it is estimated the current capacity utilization in the industry is only 50 percent.[35]

7.1.4.5 Prices. Prices are not available from published documents. A 1978 estimate of the price is $1.289/kg ($0.585/lb).[34] Using producer price indexes for flat and container glass, one can estimate the October, 1982 price. The estimate is $1.790/kg ($0.812/lb).

7.1.5 Incandescent Light Bulb Blanks

7.1.5.1 Introduction. In 1979 two firms produced incandescent light bulb blanks in 7 plants located in five states. All plants were located in the Eastern region of the United States.[38]

7.1.5.2 Market Concentration. In 1979, Corning Glass and General Electric produced virtually all of the incandescent light bulb blanks manufactured in the United States for both residential and non-residential use. Both firms are large, integrated, multi-product, multi-national companies.[38]

7.1.5.3 Supply. As in other areas of lighting manufacture, capital investment requirements for entry into this market are huge. These light bulb blanks are produced on the Corning ribbon machine, the cost of which is estimated at $25 million in 1978 dollars. The very large inventory of finished goods that must be maintained further limits available capital. The characteristics of this category suggest a highly oligopolistic industry in which few firms participate and the capital requirements are so vast as to preclude the entry of small firms.[38] Imports play a role in this industry, but there are no estimates of the relative importance of imports in the domestic market.[38]

7.1.5.4 Demand. There are no viable substitutes for an incandescent bulb blank except insofar as consumers switch to fluorescent lighting. Demand for the product is consistent with demand for electrical lighting as a way of life.[39]

Consumer taste plays some very small role as a demand determinant in the end product market. Preference for other forms of lighting, such as fluorescent or neon tubing for residential use, influences demand. Mercury vapor and high-pressure sodium vapor lights, superior to incandescent lights in the amount of energy consumed, are new products being developed. To the extent that product substitutes are limited, demand appears to be relatively price-inelastic.[39]

Demand does depend on the state of the economy, as it does for fluorescent lights. At present, the estimated capacity utilization rate in this industry is 50 percent.[35]

7.1.5.5 Prices. The price per unit weight of incandescent light bulb blanks is difficult to estimate. The estimated price in 1978 was $0.766/kg ($0.352/lb).[34] Using the producer price indexes for flat and container glass, an estimate of the October, 1982, price can be made. The estimate is $1.076/kg ($0.488/lb).

7.1.6 Television Picture Tube Envelopes

7.1.6.1 Introduction. Three firms produce color TV picture tube envelopes in five plants. One firm (Corning Glass) has announced plans to close one of its plants.[40] In addition, Owens-Illinois produces black and white TV envelope tubes.[41]

7.1.6.2 Market Concentration. The industry is highly concentrated. Corning Glass, Owens-Illinois and RCA, are the only firms participating in this category of the industry. RCA produces for its own consumption.[40]

7.1.6.3 Supply. The major factor influencing the supply of television envelope tubes is the size of imports of the end-product, television sets. Imports of television sets are significant, particularly from Japan. It is estimated that imports control the black and white TV market and the smaller (15 to 16 inch) colored TV market. The 19 inch market is highly competitive between U.S. producers, on the one hand, and foreign producers, on the other. Domestic producers control the market for larger sets.[40]

7.1.6.4 Demand. Demand for TV tube envelopes is derived from demand for TV sets. The market for new TV sets accounts for 90 to 95 percent of demand for TV envelope picture tubes, the remaining 5-10 percent being the replacement market.[40]

Television sets are a luxury item representing a large expenditure from personal disposable income. The state of the general economy is an indicator of how demand for a luxury item will rise or fall, depending on whether consumers defer purchases until a more economically auspicious time.[42] The industry is currently operating at a capacity utilization rate of 67 percent.[40]

7.1.6.5 Prices. The estimated 1982 price of TV envelope tubes is \$1.102/kg (\$0.500/lb).[40] This price per unit weight can be expressed in October, 1982, dollars using the producer price indexes for flat and container glass. In that case, price is \$1.107/kg (\$0.503/lb).

7.1.7 Scientific And Technical Glass Tubing

7.1.7.1 Introduction. In 1979, tubing for medical and pharmaceutical uses was produced by four major firms in ten plants located in seven states. With the exception of one plant located in Illinois, all of the plants were located in the Eastern section of the U.S.[43]

7.1.7.2 Market Concentration. The industry is highly concentrated. In 1979, the four firms in this industry were: Owens-Illinois, Corning Glass, Schott Optical Glass, and Wheaton Glass.[43]

7.1.7.3 Supply. Very little is known about supply conditions in the industry. Scientific and technical tubing are imported into the U.S. The extent to which they penetrate the market for medical-pharmaceutical products cannot be estimated from available public data.[44]

7.1.7.4 Demand. Demand in this category is influenced by the specialized nature of the products being manufactured and is relatively price-inelastic. Growth and advances in technology in the medical and health-related industries will influence demand. Viable substitutes from some products in this area include plastics and ceramic glass. In that both Owens-Illinois and Corning Glass maintain full production capabilities in both of these areas, substitutability of other goods is not anticipated to influence demand in terms of Owens-Illinois and Corning Glass in this market.[45]

7.1.7.5 Prices. It is difficult to arrive at an estimate of the price per unit weight for this product category. An August, 1978, estimate was \$1.168/kg (\$0.530/lb).[28] Using the producer price indexes for container and flat glass, the October, 1982, estimate is \$1.596/kg (\$0.724/lb).

7.1.8 Optical Glass.

7.1.8.1 Introduction. In 1979, five firms in this category produced optical glass products in 8 plants located in New York, Massachusetts, Virginia, and Pennsylvania.[46]

7.1.8.2 Market Concentration. The presence of only five major firms in the industry indicates a high degree of concentration. Corning Glass, American Optical, Bausch and Lomb, Eastman Kodak, and Schott Optical Glass predominate in the industry.[46]

7.1.8.3 Supply. The major firms in this sector of the industry are also engaged in end-product manufacture of a wide range of analytical, technical, electronic, and health-related diagnostic instruments. The sector is highly specialized with products being produced largely by contract arrangement or to fill intra-company needs. To that extent, small inventories exist and no real impact is experienced from imported end-products.[46]

No significant export market exists for the glass itself, except to an existing foreign subsidiary. End-product export reflects the specialized contract nature of this category and is relatively insignificant.[46]

7.1.8.4 Demand. Optical glass and instruments are a highly specialized, high-priced, low-volume category. Demand is influenced by any growth of the electronic market, and by an expansion in government scientific and research programs. Optical glass for use in analytical instruments experiences increased demand when environmental, industrial, and aerospace programs are initiated or expanded. Any advance in biomedical research techniques brings about increased demand in this category.[47]

Plastics have become viable substitutes in some areas of ophthalmic and instrument lens production. Plastics are, however, more expensive than glass in a sector where prices are high for glass products. In uses where weight is a factor, plastics have become a viable substitute.[47]

The highly specialized, high-priced, low-volume nature of this category of the industry appears to indicate that price elasticity of demand is relatively inelastic.[47]

7.1.8.5 Prices. The prices per unit weight of optical glass was estimated to be $9.014/kg ($4.09/lb) in August, 1978.[28] Using the producer price indexes for flat and container glass, an estimate of the October, 1982, price can be made. The estimate is $12.320/kg ($5.59/lb).

7.1.9 Glass Products That Have Contained Arsenic

There are two glass products that have contained arsenic in the past. They are flat glass and container glass. Each is discussed in turn.

7.1.9.1 Flat Glass

7.1.9.1.1 Introduction. Flat glass is window glass primarily used in the automobile and construction industries.[48] In 1979, there were 27 manufacturing plants operating in 14 different states. The plants were, however, concentrated in 4 states: California, Pennsylvania, Tennessee, and West Virginia.[49]

7.1.9.1.2 Market concentration. The flat glass industry is highly concentrated, with only 8 companies currently participating in the primary manufacturing sector: PPG Industries, Inc.; Libbey-Owens-Ford Co. (LOF); Ford Motor Co., Glass Division; Guardian Industries Corp.; AFG Industries, Inc.; Hortis Brothers; Jeanette Flat Glass; and West Virginia Flat Glass Company.[50] The four largest companies (PPG, LOF, Ford, and Guardian) controlled 86.7 percent of total domestic production capacity in 1977. PPG dominates the construction market, and Libbey-Owens-Ford dominates the automotive market.[51]

7.1.9.1.3 Total supply

Domestic supply. The plants in the flat glass industry have operated at less than full capacity in recent years because of the slumps in domestic automobile production and housing. New office building construction has, however, continued to be a major source of demand and has raised operating rates from their otherwise depressed levels. In addition, truck and bus production has increased slightly.[48]

Imports and exports. In 1982, exports were estimated to be 8.7 percent of industry shipments, and imports were estimated to be 3.9 percent of apparent consumption (the sum of product shipments plus imports less exports). The current situation in which exports exceed imports by a comfortable margin is an improvement that has occurred during the last decade. This change has been attributed to the industry's shift to float-glass production techniques (which reduced unit costs) and to relatively low costs for natural gas. As natural gas prices increase in the coming years, U.S. producers may lose their present competitive advantage in world markets.[48]

The principal market for exports and imports of flat glass is Canada.[52] Other important export markets are Mexico, Venezuela, and Australia. In addition to Canada, West Germany and Japan are leading suppliers to the U.S.[48]

7.1.9.1.4 Total demand. The demand for flat glass depends on (1) the demand for new automobiles and new residential and nonresidential construction, (2) the demand for the retrofitting of additional thermal glass to existing structures, (3) the repairing of existing glass in automobiles and construction, and (4) the size of automobiles and houses.

Table 7-7 presents the output, shipments, and average price paid for flat glass from 1970 to 1981. From 1977 to 1981, the flat glass industry experienced an annual compound decline in demand (output in 1,000 sq. ft.) of 2.2 percent. This decline has been attributed to two factors: (1) the cyclically depressed state of the domestic markets for new automobiles and houses, and (2) the longer, secular shift to smaller automobiles and smaller houses, which require less glass per unit.[53] Output of flat glass is expected to recover as the housing and construction industries improve. It has been estimated that the industry will grow at an annual compound rate of 5 percent during the 1982-1987 period.[53]

Although physical output declined, Table 7-7 shows that value of shipments rose from 1977 to 1981 by 6.5 percent. This was due to the increase in the average price paid of 8.9 percent during the same period of time.

7.1.9.1.5 Prices. Prices of flat glass are typically measured as price per 1,000 square feet. As Table 7-7 shows, the price of flat glass in

Table 7-7

SHIPMENTS, OUTPUT, AND PRICES OF FLAT GLASS, 1970 TO 1981[54-60]

	Flat Glass		
	Quantity (1,000 sq. ft.)	Value of Shipments ($1,000)	Price ($ Per 1,000 sq. ft)
1970	NA[a]	384,790	NA
1971	NA	464,674	NA
1972	NA	544,875	NA
1973	NA	597,645	NA
1974	NA	543,382	NA
1975	NA	467,994	NA
1976	NA	644,751	NA
1977	2,897,025	739,919	255
1978	3,099,841	829,449	268
1979	2,974,460	858,130	288
1980	2,749,948	868,459	316
1981	2,652,609	952,283	359
Annual Compound Growth Rates			
1970 to 1981	NA	8.6	NA
1977 to 1981	-2.2	6.5	8.9

[a] NA = not available.

1981 was $359 per 1,000 square feet. If prices are measured in price per unit weight, flat glass is estimated to have sold at $0.456/kg ($0.207/lb) in the second quarter of 1982.[61]

This data can be expressed in October, 1982, prices by using the producer price index for flat glass. In October, 1982, dollars the price of flat glass was $0.461/kg ($0.209/lb).

7.1.9.2 Container Glass

7.1.9.2.1 Introduction. The beer, food products, liquor/wine, and soft drink beverage markets accounted for over 90 percent of glass container production in 1981.[62] Other markets served were medicinal and health supplies, toiletries and cosmetics, and industrial products.[62]

In 1977, there were 123 container glass manufacturing plants located in 30 states.[63] Currently, it is estimated there are 24 to 29 companies and 110 plants in operation.[64]

7.1.9.2.2 Market concentration. The container glass industry is concentrated. In 1979, the four largest companies accounted for 56 percent of sales, with the next four largest companies accounting for an additional 21 percent of sales.[63]

In 1976, Owens-Illinois, Inc., was reported to have a 28.9 percent share of the container glass market, with Brockway Company, Inc. having the next largest share, 11.4 percent. Other companies ranking among the first 10 in 1976 market share included: Anchor Hocking, Thatcher Glass, Glass Containers Corp., Kerr Glass, Indian Head, Ball Corp., Chattanooga Glass, and Midland Glass.[63]

7.1.9.2.3 Total supply. Because glass containers have a high weight to volume, they are located as close as possible to the market they are intended to serve. Plants are sometimes dedicated to servicing the needs of one nearby customer (for example, a brewery).[63]

The desire of container glass manufacturers to relocate production closer to its customers led to a wave of expansions in the years 1972-1977.[65] This has led to some overcapacity in the industry because of three factors: (1) increased competition from substitutes, especially plastic bottles and metal cans; (2) decreased consumption of bottled products due to the current recession; and (3) a tendency to use lighter weight bottles.[66]

Exports and imports. International trade is insignificant in the glass container industry, chiefly because glass containers have a high weight to volume. Exports were only .9 percent of shipments in 1981, and imports were only 2.1 percent of apparent consumption.[67]

7.1.9.2.4 Total demand. The demand for container glass depends on (1) the demand for its end products, chiefly beer, food products, and soft drink beverages, (2) the existence and use of substitutes for glass in containers, and (3) the amount of glass recycling. Glass container manufacturers face competition from metal cans and from plastic bottles. The industry is currently said to be especially concerned about the substitution of plastic bottles for glass containers in the wine and soft drink beverage market.[68]

Table 7-8 summarizes the growth in output, shipments, and price for all containers from 1970 to 1981. From 1970 to 1981, the container glass industry experienced an annual compound growth rate in physical output (1,000 gross) of 1.6 percent. Although output has increased only 1.6 percent since 1970, value of shipment has increased 9.7 percent. This higher growth rate in value of shipments is due to the increase in the average price paid for containers of 8.0 percent.

7.1.9.2.5 Prices. Prices of container glass are typically measured in price per 1,000 gross. As Table 7-8 shows, the price of container glass in 1981 was $15,871 per 1,000 gross. If prices are measured in price per unit weight, it is estimated container glass sold at $0.419/kg ($0.190/lb) in 1981.[69]

This figure can be updated to an October, 1982, price by using the producer price index for container glass. The estimate is $0.456/kg ($0.207/lb).

Table 7-8

SHIPMENTS, OUTPUT AND PRICE OF CONTAINERS, 1970 TO 1981[70-75]

	Domestic Glass Containers		
	Quantity (1,000 Gross)	Value of Shipments ($1,000)	Price ($ Per 1,000 Gross)
1970	266,031	1,815,456	6,824
1971	255,261	1,907,550	7,473
1972	265,981	2,062,403	7,754
1973	274,295	2,208,245	8,051
1974	273,709	2,475,168	9,043
1975	279,022	2,929,814	10,500
1976	292,345	3,294,089	11,268
1977	304,114	3,570,147	10,740
1978	317,440	4,023,458	12,675
1979	319,842	4,234,851	13,240
1980	323,899	4,540,764	14,019
1981	316,408	5,021,865	15,871
Annual Compound Growth Rates			
1970 to 1981	1.6	9.7	8.0
1975 to 1981	2.1	9.4	7.1

7.2 Economic Analysis

7.2.1 Introduction

Section 7.2 presents the analysis of the economic impacts of alternatives to regulating inorganic arsenic emissions from the glass industry. Three principal economic impacts are analyzed. First, Section 7.2.4.1 analyzes the impact on prices. Second, Section 7.2.4.2 analyzes the impact on profitability. Third, Section 7.2.4.3 analyzes the ability of firms to obtain the capital required to meet the standards. Two regulatory alternatives are evaluated: (1) standards based on the use of an evaporative cooler followed by an electrostatic precipitator (ESP) or a fabric filter (FF) and (2) standards that ban arsenic emissions. Section 7.2.4.4 discusses the economic impact of banning arsenic emissions in glass manufacturing plants.

7.2.2 Summary

There are several results of the evaluation of price impacts, profit impacts, and capital availability that should be mentioned briefly. It should be noted that the conclusions discussed below are generally the same for the ESP and FF options, exceptions being flat and container glass. Also, the price and profit impact results were not evaluated for the actual furnaces at the 15 plants that are likely to be affected, but rather for hypothetical furnaces of a particular size and producing a particular product. Only some of these "model plant" furnaces are representative of the furnaces at the 15 plants identified as producing arsenic-containing glass. Where model plant furnace impacts do not depict impacts expected at actual plants (because no arsenic is used), this is noted in the discussion.

Six model plant sizes and two or three levels of capacity utilization are evaluated. In this analysis the assumption is made in cases of 25 and 50 percent capacity utilization that all control costs can be passed on only to the arsenic-containing products and not to all products produced in the same furnace. An alternative assumption is that control costs are distributed to the entire product line produced by the furnace (including products that do not contain arsenic). If the latter occurs, price and profit impacts are lower than those reported here.

In the case of price impacts, the larger size furnaces (45 megagrams per day (Mg/D) through 636 Mg/D) have modest potential price increases, whereas the smaller furnaces (4.5 Mg/D) and 23 Mg/D) have more significant increases. Maximum price increases are particularly large for borosilicate incandescent bulb blanks, borosilicate tubing, and TV envelope tubes, reaching 11.6, 8.2, and 13.3 percent respectively. In the case of TV envelope tubes, it is more likely that the control costs will be absorbed by the producers, rather tnan passed on to consumers, because of the competitive role of imports. No information is available about the likely absorption of costs for the other two products. However, none of the actual 19 furnaces that are expected to have to install add-on controls as a result of the regulation produce these three products.

Profit impacts also vary substantially with furnace size. At the smallest furnace size (4.5 Mg/D or 23 Mg/D) and 25 percent capacity utilization, the results for all products but optical glass indicate a furnace closure or a product elimination as a potential result. On the other hand, for large furnaces (45 Mg/D through 636 Mg/D), the profit impacts are generally small. Just as with the case of maximum price increases, three products show the greatest potential for closure at small furnace sizes. They are borosilicate incandescent bulb blanks, borosilicate tubing, and TV envelope tubes. However, none of the actual 19 furnaces that are expected to have to install add-on controls as a result of regulations produce these three products.

There are no major problems with raising the necessary capital for either of the two firms requiring controls. Although control capital costs are not trivial sums, the affected firms are large and should be able to raise the necessary capital.

7.2.3 Methodology

Several aspects of the methodology for the evaluation of impacts should be mentioned. One is that prices per unit weight are difficult to establish for the products in SIC 3229. Prices per unit weight are not only not published in standard references such as Current Industrial Reports or the American Glass Review, but they are not readily available from industry sources. With the exception of TV envelope tubes, prices per unit weight in SIC 3229 are based on 1978 information and updated to October, 1982, by using the producer price indexes for container and flat glass.

A second aspect of the methodology that should be noted is that all of the companies involved in the analysis are large firms with multiple products. As a result, pre-control financial ratios for individual products are not available on an isolated basis. The analysis of profit impacts is, therefore, based on business segments containing the affected product but also other products.

Third, several products may be produced by a glass melting furnace, however not all of these products contain arsenic. For example, in the case of handmade consumer glass, crystal stemware typically uses arsenic, but other glass products produced in the same furnace do not. As a result, this analysis uses capacity utilization rates of 25 and 50 percent (as well as 100%) to take into account the fact that not all products produced in a given furnace use arsenic. The assumption is made in these cases of 25 and 50 percent capacity utilization that all of the control costs will be assigned only to the arsenic-containing products and not to all products manufactured in the same furnace. An alternative assumption is that control costs may be distributed among all products produced in the same furnace whether or not they use arsenic. This alternative assumption would reduce the price and profit impacts reported in Sections 7.2.4.1 and 7.2.4.2.

A fourth aspect of the methodology is that model plant furnaces are used to evaluate the economic impact of the regulatory alternatives. Although model plant furnaces include characteristics that represent worst case situations of actual furnaces, they are not designed to duplicate exactly any actual furnace. In fact, as mentioned previously, only some of the model furnaces are representative of the 32 furnaces that have been identified as producing arsenic-containing glass.

Finally, data on specific companies have been used to derive pre-control financial characteristics of the industry for purposes of the impact analysis. Standard references for industry financial data, such as Robert Morris Associates, are not available for the glass industry. As a result it is not possible to cross check information to the degree that would typically be desirable.

7.2.4 Results

7.2.4.1 Price Impacts. In order to evaluate the maximum impact that control costs can have on prices, a simplifying assumption is made whereby the plants increase their prices of arsenic containing glass to the point where all control costs are passed through to their customers. Maximum price increases are thus a "worst case" from the point of view of the consumer. One can approximate the maximum percentage increase in price by expressing the annualized costs of control as a percent of sales (revenues) before controls. A complete pass forward of control costs may not be possible in every case, and later this assumption is relaxed when profit impacts are evaluated. However, assuming a complete pass forward is possible in every case introduces a common reference point, which then facilitates comparisons of various alternatives and scenarios.

The above approach does not consider the investment tax credit, and therefore is a conservative approach that will tend to overstate the impact of the control costs. Other approaches can also be used to determine price increases. For example, a net present value (NPV) approach could be used. In an NPV approach the revenue increase necessary to exactly offset the control costs is determined such that the NPV of the plant remains constant. An NPV analysis can also take into account the investment tax credit, depreciation over the applicable time period, income taxes, the time value of money as well as capital costs, and operating and maintenance (O&M) costs. Although the NPV approach is a more complicated calculation that takes into account more variables than the simplified approach described above, the two approaches yield similar results. The method described above is preferable in this case due to its straightforward approach, ease of presentation, and reasonable results.

Table 7-9 summarizes the maximum percent price increases for all products and each control option of the regulatory alternative that calls for standards based on the use of an ESP or fabric filter. The effects on prices of alternative furnace sizes and rates of capacity utilization are also presented. The results shown on Table 7-9 are discussed on an individual product basis and in more detail in the sections below.

7.2.4.1.1 Soda lime incandescent bulb blanks. The maximum price increases for soda lime incandescent bulb blanks are below 2 percent for the

Table 7-9

MAXIMUM PERCENT PRICE INCREASES

		Model Plant Size, Mg/Day (Tons/Day)												
		4.5 (5)			23 (25)			45 (50)		91 (100)		181 (200)		636 (700)
		Capacity Utilization[b] at			Capacity Utilization at			Capacity Utilization at		Capacity Utilization at		Capacity Utilization at		Capacity Utilization at
Product	Control Option[a]	25%	50%	100%	25%	50%	100%	70%	100%	70%	100%	70%	100%	70%	100%
Incandescent bulb blanks (soda lime)	ESP	-[c]	-	-	-	-	-	3.5	2.5	2.5	1.7	-	-	-	-
	FF	-	-	-	-	-	-	3.1	2.2	2.1	1.5	-	-	-	-
Incandescent bulb blanks (borosilicate)	ESP	-	-	-	11.6	5.8	2.9	2.5	1.7	1.8	1.2	-	-	-	-
	FF	-	-	-	10.9	5.5	2.7	2.2	1.5	1.5	1.0	-	-	-	-
Optical glass	ESP	2.7	1.3	0.7	1.2	0.6	0.3	0.3	0.2	0.2	0.1	-	-	-	-
	FF	3.5	1.7	0.9	1.1	0.6	0.3	0.2	0.2	0.2	0.1	-	-	-	-
Handmade consumer ware	ESP	3.9	2.0	1.0	1.7	0.9	0.4	0.4	0.3	0.3	0.2	-	-	-	-
	FF	5.1	2.5	1.3	1.6	0.8	0.4	0.3	0.2	0.2	0.2	-	-	-	-
Machine-made consumer ware	ESP	-	-	-	3.3	1.7	0.8	0.7	0.5	0.5	0.4	0.5	0.3	-	-
	FF	-	-	-	3.1	1.6	0.8	0.6	0.4	0.4	0.3	0.3	0.2	-	-
Tubing (borosilicate)	ESP	-	-	-	8.2	4.1	2.1	1.7	1.2	1.2	0.9	-	-	-	-
	FF	-	-	-	7.7	3.8	1.9	1.6	1.1	1.1	0.7	-	-	-	-
TV envelope tubes	ESP	-	-	-	13.3	6.6	3.3	2.8	2.0	2.0	1.4	-	-	-	-
	FF	-	-	-	12.4	6.2	3.1	2.5	1.8	1.7	1.2	-	-	-	-
Flat glass	ESP	-	-	-	-	-	-	-	-	-	-	-	-	1.4	1.0
	FF	-	-	-	-	-	-	-	-	-	-	-	-	2.7	1.9
Container glass	ESP	-	-	-	-	-	-	-	-	-	-	3.5	2.4	-	-
	FF	-	-	-	-	-	-	-	-	-	-	3.0	2.1	-	-

[a] FF = evaporative gas cooler followed by a fabric filter (FF). ESP = evaporative gas cooler followed by an electrostatic precipitator (ESP).

[b] 100 percent capacity utilization is 8,400 hours/year, or 350 days/year.

[c] - = not applicable.

91 Mg/D furnace at 100 percent capacity utilization, and 2.1 to 3.5 percent in all other cases. It is likely that the control costs will be passed forward to the consumer, although there is a small but growing import market for soda lime incandescent bulb blanks. None of the furnaces that have been identified as using arsenic are known to produce soda lime incandescent bulb blanks.

7.2.4.1.2 Borosilicate incandescent bulb blanks. The maximum price increases for borosilicate incandescent bulb blanks vary from a low of 1.0 percent (at 91 Mg/D and 100 percent capacity utilization) to a high of 11.6 percent (23 Mg/D and 25 percent capacity utilization). The price impacts for the 91 Mg/D furnace, the 45 Mg/D furnace and the 23 Mg/D furnace at 100 percent capacity utilization are less than 3 percent, whereas those for the 23 Mg/D furnace at 50 or 25 percent capacity utilization vary from 5.5 percent to 11.6 percent. It is unknown how likely it is for these costs to be passed forward to the consumer because the specialized nature of the product makes it impossible to evaluate the industry from published data. There is, for example, no information available on the role of imports. Borosilicate bulb blanks include high and low pressure street lamps and mercury vapor lamps for automobiles.[76] These wide differences in maximum percent price increases for 91 Mg/D versus 23 Mg/D may mean the 23 Mg/D plant will have to absorb costs to compete with 91 Mg/D furnace. Of the 19 actual furnaces that are expected to have to install controls (13 already have add-on controls in place), none produces borosilicate bulb blanks.

7.2.4.1.3 Optical glass. The maximum price increases for optical glass are less than 2 percent except for the cases of the smallest furnace sizes. In the case of the 4.5 Mg/D furnace and 25 percent capacity utilization, the maximum price increases vary from 2.7 (ESP) to 3.5 (FF) percent. Because this industry contains only a few firms, and the product is specialized, it is likely these price increases will be passed on to the consumer. Mitigating this conclusion is the fact that plastics are partial substitutes for optical glass.

7.2.4.1.4 Handmade consumer glass. The maximum price increases for handmade consumer glassware are also less than 2 percent except for the cases of the smallest furnace sizes. In the case of a 4.5 Mg/D furnace at 25 percent capacity utilization, the maximum price increase is 3.9 percent (ESP) or 5.1 percent (FF). It is unlikely that all of this price increase will be passed on to consumers because the domestic industry is highly competitive. In addition, handmade consumer glassware manufacturers are threatened by competition from machine-made glassware and from imports. The likelihood of pass-through versus absorption influences an evaluation of percent price increase.

7.2.4.1.5 Machine-made consumer glass. The maximum price increases for machine-made consumerware are less than 2 percent for the larger furnaces (45 Mg/D through 181 Mg/D)), but they are of some importance in the case of the 23 Mg/D furnace operating at 25 percent of capacity utilization, for which price increases vary from 3.1 (FF) percent to 3.3 (ESP) percent. It is unlikely that all of control costs will be passed on to the consumer or applied to only the arsenic requiring glass, however, because of the role of imports. Most of the existing furnaces that have been identified as using arsenic produce machine-made consumer glass.

7.2.4.1.6 Borosilicate tubing. The maximum price increases for borosilicate tubing vary from 0.7 percent at 91 Mg/D furnaces at 100 percent capacity utilization to as much as 8.2 (ESP) percent or 7.7 (FF) percent at 23 Mg/D and 25 percent capacity utilization. It is impossible to evaluate the likelihood of the control costs being passed on to the consumer, because borosilicate tubing is said to cover hundreds of end-products for which data are unavailable. Among the uses of borosilicate tubing are: scientific glassware; pharmaceutical glassware; process tubing for the food and dairy industry; bulbs for microwave ovens; electronic tubes; encapsulators for semiconductors; photomultiplier tubes; ultraviolet light transmitting tubing; photoflash bulbs; blueprint cylinders; exhaust tubing for seal-beam headlights; and control rods for nuclear reactors.[77] The wide differences in the percent increase for 91 Mg/D versus 23 Mg/D may mean the 23 Mg/D furnaces will have to absorb control costs to compete with the 91 Mg/D furnace. Of the 19 actual furnaces that are expected to have to install controls (13 already have add-on controls in place), none produces borosilicate tubing.

7.2.4.1.7 TV envelope tubes. The maximum price increases for TV envelope tubes are 2 percent or less for the 45 Mg/D and 91 Mg/D furnace but they may be as high as 13.3 percent (ESP) or 12.4 percent (FF) for the 23 Mg/D furnace at 25 percent capacity utilization. It is unlikely the costs of control will be passed on to the consumer because of the substantial role of imports, particularly from Japan. These wide differences in the percent increase for the 91 Mg/D furnace and the 23 Mg/D furnace may mean the 23 Mg/D furnace will have to absorb control costs or distribute costs to the furnaces entire product line to compete with the 91 Mg/D furnace. Of the 19 actual furnaces that are expected to install controls (13 already have add-on controls in place), none produces TV envelope tubes.

7.2.4.1.8 Flat glass. The maximum price increases are less than 2 percent for flat glass at 100 percent capacity utilization and for the ESP option at 70 percent but are 2.7 percent at 70 percent capacity utilization with the FF option. It is unlikely the costs of control will be passed on to the consumer because imports play a role in this market. However, because arsenic is not now used in the production of flat glass, any arsenic emission regulation would not affect this industry segment.

7.2.4.1.9 Container glass. The maximum price increases for container glass vary from a low of 2.1 percent for the FF option at 100 percent capacity utilization to a high of 3.5 percent for the ESP option at 70 percent capacity utilization. It is likely the costs of control will be passed on to the consumer, because imports do not play a role in this market. None of the 32 furnaces identified as using arsenic produces container glass.

7.2.4.2 Profit Impacts. The estimation of maximum profit impacts is based on the opposite assumption of the maximum price increase; namely, that plants are unable to increase their prices in order to cover the control costs. It is thus a "worst case" from the point of view of the firm. In this situation all control costs are treated as additions to baseline operating expenses. If prices are not increased, net sales remain constant resulting in a reduction of profit before taxes.

The extent to which profit is reduced can be seen by comparing the baseline before tax return on sales with before tax return on sales after controls. Return on sales is defined as profit before tax divided by total revenue. Before tax profits are used rather than after tax profits to avoid the complication of varying tax rates.

Table 7-10 to 7-17 presents background financial data for eight firms: Corning Glass, RCA, Anchor Hocking, GTE, Owens-Illinois, General Electric, PPG and Libbey-Owens-Ford. Although General Electric is not of principal concern, it is included here because it is a major manufacturer of incandescent bulb blanks and therefore its financial results are likely to add perspective to the analysis. PPG and Libbey-Owens-Ford are included to provide financial data on the flat glass industry.

Table 7-18 summarizes Table 7-10 to 7-17 about the existing ratios of before tax profits to sales for each product category. The assumptions were developed by combining the appropriate business segments in Tables 7-10 to 7-17. For example, the ratio of profits to sales for machine-made consumer glassware is an average of the ratio of profits to sales for that business segment at Anchor Hocking and at Corning Glass (using both the unadjusted and adjusted figures). The averages are unweighted due to data limitations. Several years (3 or 4) are used to be more representative. Business segment information is the best financial information available and is believed to be quite reasonable. However, other products in addition to the one under analysis are included in business segments.

Table 7-19 presents the results of the profit imports, namely, the percent change in before tax profits to sales for all products and each control option of the regulatory alternative that calls for standards based on the use of an ESP or fabric filter. The effects on profits of alternative furnace sizes and rates of capacity utilization are also presented. The results shown on Table 7-19 are discussed on an individual product basis and in more detail in the sections below.

7.2.4.2.1 Soda lime incandescent bulb blanks. The profit impacts for soda lime incandescent bulb blanks vary from 11.1 percent for the 91 Mg/D furnace at 100 percent capacity utilization (FF) to 26.4 percent (ESP) for the 45 Mg/D furnace at 70 percent capacity utilization. As indicated in the discussion of price impacts, it is more likely that control costs will be passed on to the consumer rather than being absorbed by the firm although there is currently a small market for imported bulb blanks. None of the furnaces that have been identified as using arsenic are known to produce soda lime incandescent bulb blanks.

Table 7-10

FINANCIAL CHARACTERISTICS OF CORNING GLASS WORKS, 1978 TO 1981[74,75]

(\$ 10^6)

Year	Company Total[a]	Machine-made and Handmade Consumer Glassware[b] Unadjusted	Machine-made and Handmade Consumer Glassware[b] Adjusted[c]	Picture Tube Envelopes and Incandescent Light Bulb Blanks Unadjusted	Picture Tube Envelopes and Incandescent Light Bulb Blanks Adjusted[c]	Optical Glass Unadjusted	Optical Glass Adjusted[c]
				Sales			
1978	1,251.7	331.1		373.7		245.4	
1979	1,421.6	357.1		423.6		291.9	
1980	1,529.7	374.5		443.7		350.6	
1981	1,598.5	428.8		416.8		374.4	
				Profits Before Taxes			
1978	120.6	63.8	31.1	91.5	54.6	31.8	7.6
1979	114.4	46.6	16.4	85.6	49.8	49.4	24.7
1980	85.1	32.5	-.29	8.42	45.4	60.7	30.0
1981	57.6	57.5	17.1	65.3	26.0	66.9	31.6
				Assets[a]			
1978	1,224.4	167.5	317.5	186.3	355.6	148.4	259.6
1979	1,385.2	197.6	357.7	181.0	371.0	158.8	289.7
1980	1,499.6	224.6	383.9	199.1	387.8	204.8	353.9
1981	1,613.4	241.6	422.9	204.2	380.4	228.6	386.8

Table 7-10

(Continued)

Year	Company Total[a]	Machine-made and Handmade Consumer Glassware[b]		Picture Tube Envelopes and Incandescent Light Bulb Blanks		Optical Glass	
		Unadjusted	Adjusted[c]	Unadjusted	Adjusted[c]	Unadjusted	Adjusted[c]
				Return on Sales (percent)			
1978	9.63	19.27	9.4	24.48	14.61	12.96	3.08
1979	8.05	13.05	4.6	20.21	11.75	16.92	8.45
1980	5.56	8.68	-0.08	18.98	10.22	17.31	8.55
1981	3.60	13.41	3.98	15.67	6.24	17.87	8.44
Average	6.71	13.60	4.48	19.84	10.71	16.27	7.13
				Before Tax Return on Investment (percent)			
1978	9.85	38.09	9.81	49.11	15.35	21.43	2.92
1979	8.26	23.58	4.60	47.29	13.42	31.11	8.52
1980	5.67	14.47	-0.08	42.29	11.70	29.64	8.47
1981	3.57	23.80	4.04	31.98	6.83	29.27	8.17
Average	6.84	24.99	4.59	42.67	11.84	27.86	7.02
				Sales to Assets (ratio)			
1978	1.02	1.98	1.04	2.01	1.05	1.65	.95
1979	1.03	1.81	1.00	2.34	1.14	1.84	1.01
1980	1.02	1.67	1.00	2.23	1.14	1.71	.99
1981	.99	1.77	1.01	2.04	1.10	1.64	1.00
Average	1.02	1.81	1.01	2.16	1.11	1.71	1.00

[a] Business segments shown do not sum to the company total because not all of the company's segments are shown here.

[b] Based on the business segment which includes the product under analysis as well as other products.

[c] In the adjusted figures, the general corporate income from operations and assets are distributed among business segments based on their proportion of sales.

Table 7-11

FINANCIAL CHARACTERISTICS OF RCA, 1978 TO 1981[80,81]

($ 10^6)

Year	Company Total	TV Picture Tube Envelopes
	Sales	
1978	6,600.6	962.8
1979	7,454.6	1,113.0
1980	8,001.3	1,280.5
1981	8,004.8	1,196.4
	Profits Before Taxes	
1978	514.6	103.4
1979	471.5	97.1
1980	507.3	95.7
1981	98.3	-55.7
	Assets	
1978	N/A[a]	N/A
1979	6,058.3	N/A
1980	7,147.6	N/A
1981	7,856.7	N/A
	Return on Sales (percent)	
1978	7.80	10.74
1979	6.32	8.72
1980	6.33	7.47
1981	1.23	-4.66
Average	5.42	5.57
	Before Tax Return on Investment (percent)	
1978	N/A	N/A
1979	7.78	N/A
1980	7.10	N/A
1981	1.25	N/A
Average	5.38	
	Sales to Assets (ratio)	
1978	N/A	N/A
1979	1.23	N/A
1980	1.12	N/A
1981	1.02	N/A
Average	1.12	

[a] N/A = not available.

Table 7-12

FINANCIAL CHARACTERISTICS OF ANCHOR HOCKING CORPORATION, 1978 TO 1981[83,83]

($ 10^6)

Year	Company Total	Machine-Made Consumer Glass	Containers
		Sales	
1978	716.8	220.3	391.4
1979	785.2	269.7	411.6
1980	857.5	326.5	441.0
1981	953.4	364.8	485.8
		Profits Before Taxes	
1978	63.9	25.4	39.4
1979	53.7	34.5	27.0
1980	44.6	38.6	22.0
1981	48.9	31.1	30.4
		Assets	
1978	473.5	143.4	209.8
1979	517.0	207.7	216.4
1980	559.1	246.0	231.9
1981	584.4	259.8	227.8
		Return on Sales (percent)	
1978	8.91	11.53	10.07
1979	6.84	12.79	6.56
1980	5.20	11.82	4.99
1981	5.13	8.53	6.26
Average	6.52	11.17	6.97
		Before Tax Return on Investment (percent)	
1978	13.50	17.71	18.78
1979	10.39	16.61	12.48
1980	7.98	15.69	9.49
1981	8.37	11.97	13.35
Average	10.06	15.50	13.53
		Sales to Assets (ratio)	
1978	1.51	1.54	1.87
1979	1.52	1.30	1.90
1980	1.53	1.33	1.90
1981	1.63	1.40	2.13
Average	1.55	1.39	1.95

Table 7-13

FINANCIAL CHARACTERISTICS OF GTE, 1978 TO 1981[84]

($ 10^6)

Year	Company Total	Tubing for Fluorescent Lights
		Sales
1978	N/A[a]	1,395
1979	N/A	1,632
1980	9,979	1,905
1981	11,026	1,830
		Profits Before Taxes
1978	N/A	211
1979	N/A	233
1980	1,964	243
1981	2,229	197
		Assets
1978	N/A	1,029
1979	N/A	1,178
1980	19,525	1,306
1981	21,113	1,348
		Return on Sales (percent)
1978	N/A	15.13
1979	N/A	14.28
1980	19.68	12.76
1981	20.22	10.77
Average	19.95	13.24
		Before Tax Return on Investment (percent)
1978	N/A	20.51
1979	N/A	19.78
1980	10.06	18.61
1981	10.56	14.61
Average	10.31	18.38
		Sales to Assets (ratio)
1978	N/A	1.36
1979	N/A	1.39
1980	.51	1.46
1981	.52	1.36
Average	.51	1.39

[a] N/A = not available.

Table 7-14

FINANCIAL CHARACTERISTICS OF OWENS-ILLINOIS, 1978 TO 1981[85,86]

($ 10^6)

Year	Company Total	TV Picture Tube Envelopes	Containers
		Sales	
1978	3,111.7	246	2,481
1979	3,504.3	288	2,767
1980	3,905.7	368	3,010
1981	3,943.3	378	3,091
		Profits Before Taxes	
1978	166.5	19.7	155.2
1979	206.1	32.5	186.2
1980	261.0	48.7	253.0
1981	271.9	37.7	266.1
		Assets	
1978	2,600	277	1,775
1979	2,910	297	1,998
1980	3,066	346	1,997
1981	3,072	375	2,060
		Return on Sales (percent)	
1978	5.35	8.01	6.26
1979	5.88	11.28	6.73
1980	6.68	13.23	8.41
1981	6.90	9.97	8.61
Average	6.20	10.62	7.50
		Before Tax Return on Investment (percent)	
1978	6.40	7.11	8.74
1979	7.08	10.94	9.32
1980	8.51	14.08	12.67
1981	8.85	10.05	12.92
Average	7.71	10.55	10.91
		Sales to Assets (ratio)	
1978	1.20	.89	1.39
1979	1.20	.97	1.38
1980	1.27	1.06	1.51
1981	1.28	1.01	1.50
Average	1.24	.98	1.45

Table 7-15

FINANCIAL CHARACTERISTICS OF GENERAL ELECTRIC, 1979 TO 1981[87]

($ 10^6)

Year	Company Total	Incandescent Bulb Blanks
	Sales	
1979	22,980	5,990
1980	25,523	6,342
1981	27,854	6,643
	Profits Before Taxes	
1979	2,391	617
1980	2,493	615
1981	2,660	549
	Assets	
1979	16,644	2,500
1980	18,511	2,656
1981	20,942	2,926
	Return on Sales (percent)	
1979	10.4	10.3
1980	9.0	9.7
1981	9.6	8.3
Average	9.7	9.4
	Before Tax Return on Investment (percent)	
1979	14.4	24.7
1980	8.7	23.2
1981	12.7	18.8
Average	11.9	22.2
	Sales to Assets (ratio)	
1979	1.38	2.40
1980	1.38	2.38
1981	1.33	2.27
Average	1.36	2.35

Table 7-16

FINANCIAL CHARACTERISTICS OF PPG 1978-1981[88,89]

($ 10^6)

Year	Company Total	Flat Glass
	Sales	
1978	2,794	995
1979	3,092	1,097
1980	3,158	1,174
1981	3,354	1,210
	Profits Before Taxes	
1978	244	167
1979	391	174
1980	371	143
1981	352	113
	Assets	
1978	2,324	659
1979	2,955	724
1980	2,826	879
1981	2,637	897
	Before Tax Return on Sales (percent)	
1978	8.7	16.8
1979	12.7	15.9
1980	11.8	12.2
1981	10.5	9.3
Average	10.9	13.6
	Before Tax Return on Investment (percent)	
1978	10.5	25.3
1979	13.2	24.0
1980	13.1	16.3
1981	13.4	12.6
Average	12.6	19.6
	Sales to Assets (ratio)	
1978	1.20	1.51
1979	1.05	1.52
1980	1.12	1.34
1981	1.27	1.35
Average	1.16	1.43

Table 7-17

FINANCIAL CHARACTERISTICS OF LIBBEY-OWENS-FORD 1978-1981[90]

($ 10^6)

Year	Company Total	Flat Glass
	Sales	
1978	1,107.1	617.9
1979	1,208.1	630.5
1980	1,159.9	559.6
1981	1,226.5	598.7
	Profits Before Taxes	
1978	112.3	49.2
1979	112.4	44.7
1980	67.9	-6.2
1981	73.8	-14.0
	Assets	
1978	726.6	338.7
1979	846.0	424.3
1980	903.8	425.9
1981	893.0	389.1
	Before Tax Return on Sales (percent)	
1978	10.1	8.0
1979	9.3	7.1
1980	5.9	-1.1
1981	6.0	-2.3
Average	7.8	2.9
	Before Tax Return on Investment (percent)	
1978	15.5	14.5
1979	13.3	10.5
1980	7.5	-1.2
1981	8.3	-3.6
Average	11.2	5.1
	Sales to Assets (ratio)	
1978	1.52	1.82
1979	1.43	1.49
1980	1.28	1.31
1981	1.37	1.54
Average	1.40	1.54

Table 7-18

SUMMARY OF FINANCIAL RATIOS FOR PROFIT IMPACTS

Product	Before Tax Profits to Sales[a] (Percent)
Incandescent bulb blanks (soda lime)	13.3
Incandescent bulb blanks (borosilicate)	13.3
Optical glass	11.7
Handmade consumer ware	9.0
Machine-made consumer ware	9.8
Tubing (borosilicate)	6.7
TV envelope tubes	11.7
Flat glass	8.3
Container glass	7.2

[a] With one exception, the financial ratios are averages for the appropriate business segments in the firms producing that product. In the case of borosilicate tubing, however, the ratios are averages for Corning Glass as a whole, because borosilicate tubing is produced in each of Corning's business segments.

Table 7-19

PROFIT IMPACTS: PERCENT CHANGE IN BEFORE TAX PROFITS ON SALES - AFTER CONTROLS

Product	Control Option[a]	Model Plant Size, Mg/Day (Tons/Day)															
		4.5 (5)			23 (25)			45 (50)		91 (100)		181 (200)		636 (700)	
		Capacity Utilization at[b]			Capacity Utilization at			Capacity Utilization at		Capacity Utilization at		Capacity Utilization at		Capacity Utilization at	
		25%	50%	100%	25%	50%	100%	70%	100%	70%	100%	70%	100%	70%	100%
Incandescent bulb blanks (soda lime)	ESP	-[c]	-	-	-	-	-	26.4	18.5	18.7	13.1	-	-	-	-
	FF	-	-	-	-	-	-	23.4	16.4	15.9	11.1	-	-	-	-
Incandescent bulb blanks (borasilicate)	ESP	-	-	-	87.2	43.5	21.8	18.8	12.8	13.5	9.8	-	-	-	-
	FF	-	-	-	81.9	40.6	20.3	16.5	11.3	11.3	8.3	-	-	-	-
Optical glass	ESP	23.1	11.1	6.0	10.3	5.1	2.6	1.7	1.7	1.5	0.9	-	-	-	-
	FF	29.9	14.5	7.7	9.4	5.2	2.6	1.7	1.7	0.9	0.9	-	-	-	-
Handmade consumer ware	ESP	43.3	22.2	11.1	20.0	10.0	4.4	4.4	3.3	3.3	1.1	-	-	-	-
	FF	56.7	27.8	14.4	18.9	8.9	4.4	3.3	2.2	2.2	2.2	-	-	-	-
Machine-made consumer ware	ESP	-	-	-	33.7	17.3	8.2	7.1	5.1	5.1	3.1	5.1	4.1	-	-
	FF	-	-	-	31.6	16.3	8.2	6.1	4.1	4.1	3.1	3.1	2.0	-	-
Tubing (borasilicate)	ESP	-	-	-	122.4	61.2	31.3	25.4	17.9	17.9	13.4	-	-	-	-
	FF	-	-	-	113.4	58.2	30.0	23.9	16.4	16.4	10.4	-	-	-	-
TV envelope tubes	ESP	-	-	-	113.7	56.4	28.2	23.9	17.1	17.1	12.0	-	-	-	-
	FF	-	-	-	106.0	53.0	26.5	20.5	15.4	14.5	10.3	-	-	-	-
Flat glass	ESP	-	-	-	-	-	-	-	-	-	-	-	-	16.9	12.0
	FF	-	-	-	-	-	-	-	-	-	-	-	-	32.5	22.9
Container glass	ESP	-	-	-	-	-	-	-	-	-	-	48.6	33.3	-	-
	FF	-	-	-	-	-	-	-	-	-	-	41.7	29.2	-	-

[a] FF = evaporative gas cooler followed by a fabric filter (FF). ESP = evaporative gas cooler followed by an electrostatic precipitator (ESP).

[b] 100 percent capcity utilization is 8,400 hours/year, or 350 days/year.

[c] - = not applicable.

7.2.4.2.2 Borosilicate bulb blanks. The profit impacts on borosilicate bulb blanks vary from 8.3 percent for the 91 Mg/D furnace at 100 percent capacity utilization (FF) to 87.2 percent for the 23 Mg/D furnace at 25 percent capacity utilization (ESP). As indicated in the discussion of price impacts, it is impossible to evaluate the likelihood of profit absorption in the product category, because no information is available on the role of imports. The situation with respect to furnaces sizes is similar to that for price impacts. The wide differences in profits impacts for the 91 Mg/D furnace versus the 23 Mg/D furnace may put the 23 Mg/D furnace at a competitive disadvantage. Of the 19 actual furnaces that are expected to install controls (13 already have add-on controls in place), none produces borosilicate bulb blanks.

7.2.4.2.3 Optical glass. The profit impacts vary from 0.9 percent for the 91 Mg/D furnace at 100 percent capacity utilization to 29.9 percent for the 4.5 Mg/D furnace at 25 percent capacity utilization. As indicated in the discussion of price impacts, it is more likely that control costs will be passed on to the consumer rather than being absorbed by the firm although the role of plastic substitutes cannot be discounted.

7.2.4.2.4 Handmade consumer glass. The profit impact for handmade consumer glass varies from 1.1 percent for the 91 Mg/D furnace at 100 percent capacity utilization to 43.3 percent (ESP) and 56.7 percent (FF) for the 4.5 Mg/D furnace at 25 percent capacity utilization. As indicated in the section on price impacts, it is likely that the costs of control will be absorbed by producers because of competition from imports and from machine-made consumer ware.

7.2.4.2.5 Machine-made consumerware. The profit impacts on machine-made consumerware manufacturers vary from 2.0 percent for 181 Mg/D furnaces at 100 percent capacity utilization to 33.7 percent for the 23 Mg/D furnace at 25 percent capacity utilization. As indicated in the section on prices, it is likely producers will have to absorb costs of control because of the role of imports in this market. Most of the existing furnaces that have been identified as using arsenic produce machine-made consumer glass.

7.2.4.2.6 Borosilicate tubing. The profit impacts for borosilicate tubing varies from 10.4 percent for the 91 Mg/D furnace at 100 percent capacity utilization to 113.4 (FF) and 122.4 (ESD) percent for the 23 Mg/D plant at 25 percent capacity utilization. For the latter cases, closures are almost certain because when profit declines more than 100 percent, that means a net loss. As indicated in the section on price impacts, it is impossible to evaluate whether control costs will be passed on to the consumer or absorbed by the firm because of lack of information on the individual products in the borosilicate tubing category. The situation with respect to furnace sizes is similar to that for price impacts. The wide differences in profit impacts for the 45 Mg/D and 91 Mg/D furnace and the 23 Mg/D furnace may put the 23 Mg/D furnace at a competitive disadvantage. Of the 19 actual furnaces that are expected to have to install controls (13 already have add-on controls in place), none produces borosilicate tubing.

7.2.4.2.7 TV envelope tubes. The impact on profits varies from 10.3 percent for the 91 Mg/D furnace at 100 percent capacity utilization to 113.7 percent for the 23 Mg/D at 25 percent capacity utilization. When profits decline more than 100 percent, that means there is a net loss from operations, hence, closure is almost certain. As indicated in the discussion of price impacts, absorption of control costs by TV envelope tube producers is likely because of the role of imports. The situation with respect to furnace sizes is similar to that for price impacts. The wide differences in profit impacts for the 91 Mg/D furnace and the 23 Mg/D furnace may put the 23 Mg/D furnace at a competitive disadvantage. Of the 19 actual furnaces that are expected to install controls (13 already have add-on controls in place), none produces TV envelope tubes.

7.2.4.2.8 Flat glass. The profit impact on flat glass for the 636 Mg/D furnace with the ESP option varies from 12.0 to 16.9 percent, whereas the profit impact with the FF option varies from 22.9 to 32.5 percent. However, it is expected that the least expensive control device would be installed. As indicated in the section on prices, it is likely these profit impacts will have to be absorbed by producers because of the role of imports. However, because arsenic is not now used in the production of flat glass, the regulation would not affect this industry segment.

7.2.4.2.9 Container glass. The profit impacts for the 181 Mg/D furnace vary from 29.2 percent (ESP) at 100 percent capacity utilization to 48.6 percent (ESP) at 70 percent capacity utilization. It is unlikely, however, that these control costs will be absorbed by producers since the high weight to volume of containers precludes imports. None of the 32 furnaces identified as using arsenic produces container glass.

7.2.4.3 Capital Availability. The final topic that must be considered is the ability of the plants to finance the capital costs associated with the installation of add-on controls. In general, profitability will determine capital availability, but an explicit discussion of capital availability provides additional insight.

An examination of the long term debt to total capitalization (long term debt plus equity) ratio for the plant provides a measure of capital availability. A high ratio usually indicates that further debt financing may not be available. This percentage can then be reviewed for the firm over a period of several years as well as compared with debt ratios of similar firms in the industry. If it is assumed that the control costs are financed solely with debt, then the impact of control costs can be evaluated by adding the control costs to both the numerator and denominator. This calculation results in the debt ratio after control costs. This ratio can then be compared to the debt ratio before control costs and an evaluation made with respect to capital availability problems.

Table 7-20 summarizes the pre-control ratio of long-term debt to total capitalization for the five firms identified as currently producing glass using arsenic. All of the five firms are major publicly-held corporations. As this table shows, the precontrol ratio varies from 16.2 percent for Corning Glass to 61.6 percent for GTE. Only two of these firms, Corning Glass and Anchor Hocking, have arsenic-using furnaces that would need to install add-on controls.

Table 7-21 presents the post-control situation for Corning and Anchor Hocking based on controls costs estimated for a "worst case" (largest capital cost), namely, that all furnaces are large (91 Mg/D). Even in the case of Anchor Hocking, however, capital availability does not appear to be overly burdensome factor for two reasons: (1) it has a low ratio of long-term debt to total capitalization even with controls, and (2) the ratio after controls (27.7% and 25.7%) is below three other companies in the industry.

Table 7-20

RATIO OF LONG-TERM DEBT TO TOTAL CAPITALIZATION (PRE-CONTROL)[91-97]

	Corning Glass	Owens-Illinois	RCA	GTE	Anchor Hocking
			Long-Term Debt ($ 10^6)		
1978	163.4	691.	N/A[a]	N/A	N/A
1979	147.1	697.	1,474.2	N/A	86.5
1980	153.6	687.	1,771.2	7,468.	87.5
1981	200.1	618.	1,855.8	7,978.	85.0
Average	166.0	673.3	1,700.4	7,723.	86.3
			Total Capitalization (Long-Term Debt Plus Equity)		
1978	905.1	1,797.	N/A	N/A	N/A
1979	975.1	1,898.	3,234.0	N/A	363.6
1980	1,066.3	2,003.	4,182.6	12,016.	380.6
1981	1,165.5	2,033.	4,095.7	13,049.	393.4
Average	1,028.0	1,932.8	3,837.4	12,532.5	379.2
			Ratio of Long Term Debt to Total Capitalization (Percent)		
1978	18.1	38.5	N/A	N/A	N/A
1979	15.1	36.7	45.6	N/A	23.8
1980	14.4	34.3	42.4	62.2	23.0
1981	17.2	30.4	45.3	61.1	21.6
Average	16.2	34.8	44.3	61.6	22.8

[a] N/A - not available.

Table 7-21

RATIO OF LONG TERM DEBT TO TOTAL CAPITALIZATION (POST CONTROL)

Company	Number of Affected Furnaces	Ratio of Long Term Debt to Total Capitalization: Before Controls	After Controls[a] ESP	After Controls[a] FF	Percent Change ESP	Percent Change FF
Anchor Hocking	10	22.8	27.7	25.7	21.5	12.7
Corning Glass	9	16.2	18.0	17.2	11.1	6.2
GTE	0	61.6	NA[b]	NA	NA	NA
Owens-Illinois	0	34.8	NA	NA	NA	NA
RCA	0	44.3	NA	NA	NA	NA

[a] Assumes the worst case (largest capital cost), namely, all plants are large (91 Mg/D).

[b] Not Applicable

7.2.4.4 Impacts of Ban on Arsenic Emissions. The third regulatory alternative, that of setting a standard that would ban arsenic emissions, was evaluated also. This alternative would have an impact on the value of shipments and employment in SIC 3229 if the 15 plants closed down as a result of the ban. This is a worst case, because it is possible a plant would delete an arsenic product but continue to produce other products (non-arsenic).

It is difficult to arrive at an estimate of the impact of the closures of these 15 plants on the value of shipments in SIC 3229, because there is insufficient information available on the capacity of each of these plants. For purposes of arriving at an estimate, it is assumed each of the 32 furnaces in the 15 plants has a capacity of 45 Mg/D and revenues are calculated for 45 Mg/D furnaces at 100 percent capacity utilization. This capacity means there is $1,900.6 million in revenues (value of shipments) in the plants. As Table 7-1 showed, SIC 3229 had $2,847.5 million dollars of shipments in 1980. Under the assumptions discussed above, value of shipments in SIC 3229 would be reduced by 66.7 percent as a result of the closures.

Assuming a proportional relationship between employment and value of shipments, the effect of the plant closures on SIC 3229 can also be estimated. As Table 7-2 presented, employment in this industry was 45,700 employees. A 66.7 percent decline in employment would reduce employment by 30,482 employees (or almost 2,000 per plant on an average basis).

If there is a ban on arsenic emissions from glass manufacturing and arsenic containing glass products is discontinued, imports can be expected to increase their market share. This is particularly likely in the handmade glass sector where imports are already highly competitive with domestically produced handmade crystal.

7.3 Socio-economic Impact Assessment

7.3.1 Executive Order 12291

The purpose of Section 9.3.1 is to address those tests of macro-economic impact presented in Executive Order 12291, and, more generally, to assess any other significant macroeconomic impacts that may result from the NESHAP. Executive Order 12291 stipulates as "major rules" those that are projected to have any of the following impacts:

- An annual effect on the economy of $100 million or more.

- A major increase in costs or prices for consumers; individual industries; Federal, State, or local government agencies; or geographic regions.
- Significant adverse effects on competition, employment, investment, productivity, innovation, or the ability of U.S.-based enterprises to compete with foreign-based enterprises in domestic or export markets.

The fifth year annualized costs associated with a regulation that is based on the use of add-on controls for a "worst case" of 91 Mg/D furnaces is $9.4 million. This cost estiamte assumes that 19 of the 32 existing arsenic-using furnaces would install ESP's. If the FF option is used as an add-on control device, the fifth year annualized costs of 19 furnaces at 91 Mg/D capacity is $8.0 million. Hence, the costs of compliance are well below the $100 million which, according to Executive Order 12291, signifies a major rule.

The potential effects on consumers of a regulation that is based on the use of add-on controls were addressed in Section 7.2.4.1, and the potential effects on producers were addressed in Section 7.2.4.2. As the information in those sections makes clear, there may be a substantial impact on producers of TV envelope tubes. In the cases of borosilicate tubing and borosilicate incandescent lights, it is unclear whether the impact will fall on consumers or producers. However, none of the actual 19 furnaces that are expected to have to install add-on controls as a result of the regulation produce these products.

Based on the potential adverse impacts of furnace closure resulting from a regulation that would ban arsenic emissions, such a regulation would likely be considered a major rule.

7.3.2 Regulatory Flexibility

The Regulatory Flexibility Act (RFA) of 1980 requires that differential impacts of Federal regulations upon small business be identified and analyzed. The RFA stipulates that an analysis is required if a substantial number of small businesses will experience significant impacts. Both measures must be met, substantial numbers of small businesses and significant impacts, to require an analysis. If either measure is not met, then no analysis is required.

The Small Business Administration (SBA) definition of a small business for SIC 3229 is a firm that employs 750 persons or less.[98] Table 7-22 shows the number of glass plants by number of employees in the four States of West Virginia, Pennsylvania, Ohio, and Virginia. Of the 106 plants in these four States, at least 73 or about 70 percent are considered by SBA's definition to be small firms.

Arsenic usage by these small firms is not known. However, it is expected that at least some do use arsenic in their batch material and, therefore, have arsenic emissions. The EPA guidelines state that a regulatory flexibility analysis is required if it is expected that a regulation will have a significant impact on more than 20 percent of the small firms being affected by the regulation. Because the number of firms that may be affected and the differential impacts that might occur will depend on the form of the standard, the analysis cannot be presented in this publication. However, the analysis performed will be included in the docket for the proposed standards for arsenic emissions from glass manufacturing plants (A-83-08).

Table 7-22

PRESSED AND BLOWN GLASS NEC MANUFACTURING PLANTS IN FOUR STATES[a,99]

Number of Employees	Number of Plants	Number of Plants Owned by Small Firms[b]
1 - 9	24	24
10 - 19	8	8
20 - 49	12	12
50 - 99	10	9
100 - 499	27	20
500 - 999	13	1*[c]
>1000	3	0
Unknown	9	4[c]
TOTAL	106	78

[a] Four States are West Virginia, Pennsylvania, Ohio, and Virginia, where small glassmaking firms are chiefly located.

[b] A small firm is one with less than 750 employees.

[c] It is not known whether these plants are owned by small firms.

7.4 References

1. U.S. Department of Commerce. Bureau of the Census. Standard Industrial Classification Manual. Washington, D.C. 1972. pp. 136-137, 144.

2. U.S. Department of Commerce. Bureau of the Census. 1980 Annual Survey of Manufacturers: Value of Product Shipments. p. 18.

3. U.S. Council of Economic Advisors. Economic Report of the President: 1983. Washington, D.C. p. 163.

4. U.S. Department of Commerce. Bureau of the Census. 1977 Census of Manufacturers: Glass Products. Washington, D.C. p. 32A-5.

5. Goldfarb, J. Owens-Corning Fiberglas. Merill Lynch, Pierce, Fenner and Smith. September 28, 1982. p. 8.

6. U.S. Department of Commerce. Bureau of the Census. 1980 Annual Survey of Manufacturers: Statistics for Industry Groups and Industries. Washington, D.C. p. 16.

7. Radian Corporation. Preliminary Study of Sources of Inorganic Arsenic: Final. A report prepared for the U.S. Environmental Protection Agency (EPA 68-02-3513). p. 180.

8. Reference 7. pp. 180, 182.

9. U.S. International Trade Commission. Household Glass. USITC Publication 841. Washington, D.C. p. 2.

10. Shareef, S.A., Radian Corporation. Memo to files. Emissions data on glass furnaces at RCA Corporation.

11. Letter from Goebel, G., Kentucky Bureau of Environmental Protection to Brooks, G. W., Radian Corporation. February 11, 1982.

12. Telecon. Brooks, G. W. Radian Corporation, with Iden, C., Owens-Illinois. March 3, 1982. Conversation concerning Owens-Illinois Arsenic Emissions.

13. Letter and attachments from Murray, D.E., Anchor Hocking Corporation to S. A. Shareef, Radian Corporation. March 14, 1983. (Project Confidential File).

14. Letter and attachments from Cherill, J., Corning Glass Works to G. W. Brooks, Radian Corporation. April 7, 1982. (Project Confidential Files).

15. U.S. Department of Commerce. Bureau of the Census. Current Industrial Report: Consumer, Scientific, and Technical Glassware. MA-32E. 1981. p. 2.

16. U.S. Department of Commerce. Bureau of the Census. Current Industrial Report: Consumer, Scientific, and Technical Glassware. MA-32E. 1980. p. 3.

17. U.S. Department of Commerce. Bureau of the Census. Current Industrial Report: Consumer, Scientific, and Technical Glassware. MA-32E. 1979. p. 3.

18. U.S. Department of Commerce. Bureau of the Census. Current Industrial Report: Consumer, Scientific, and Technical Glassware. MA-32E. 1978. p. 3.

19. U.S. Department of Commerce. Bureau of the Census. Current Industrial Report: Consumer, Scientific, and Technical Glassware. MA-32E. 1976. p. 4.

20. U.S. Department of Commerce. Bureau of the Census. Current Industrial Report: Consumer, Scientific, and Technical Glassware. MA-32E. 1975. p. 4.

21. U.S. Department of Commerce. Bureau of the Census. Current Industrial Report: Consumer, Scientific, and Technical Glassware. MA-32E. 1974. p. 2.

22. U.S. Department of Commerce. Bureau of the Census. Current Industrial Report: Consumer, Scientific, and Technical Glassware. MA-32E. 1973. p. 2.

23. U.S. Department of Commerce. Bureau of the Census. Current Industrial Report: Consumer, Scientific, and Technical Glassware. MA-32E. 1972. p. 2.

24. U.S. Department of Commerce. Bureau of the Census. Current Industrial Report: Consumer, Scientific, and Technical Glassware. MA-32E. 1971. p. 2.

25. U.S. Environmental Protection Agency. Office of Air Quality Planning and Standards. Glass Manufacturing Plants: Background Information: Proposed Standards of Performance. EPA-450/3-79-005a. p. 8-32.

26. Reference 25. p. 8-33.

27. Reference 25. pp. 8-33 to 8-34.

28. Telecon. Mosley, G., Corning Glass, with Timothy, A., JACA. August 17, 1978. Data on SIC 3229.

29. Photocopies. Lasarski, R., U.S. Bureau of Labor Statistics, to Ando, F. H., JACA. February 22, 1983. BLS price indexes for flat and container glass.

30. Reference 25. p. 8-34.

31. Telecon. Kastner, F., Smith Glass, with Ando, F. H., JACA. February 28, 1983. Handmade pressed and blown consumer glassware.

32. Reference 25. p. 8-35.

33. Reference 25. p. 8-36.

34. Reference 25. pp. 8-96 to 8-98.

35. Telecon. Nelson, J., GTE, with Ando, F., JACA. March 1, 1983. Glass tubing for fluorescent lighting.

36. Reference 25. p. 8-37

37. Reference 25. p. 8-38.

38. Reference 25. p. 8-39.

39. Reference 25. p. 8-40.

40. Telecon. Wiley, L., RCA, with Ando, F., JACA. February 25, 1983. TV picture tube envelopes.

41. Telecon. Sprouse, J., Owens-Illinois, with Ando, F., JACA. March 8, 1983. TV picture tube envelopes.

42. Reference 25. p. 8-41.

43. Reference 25. p. 8-42.

44. Reference 25. p. 8-43.

45. Reference 25. pp. 8-43 to 8-44.

46. Reference 25. p. 8-44.

47. Reference 25. p. 8-45.

48. U.S. Department of Commerce. Bureau of Industrial Economics. 1983 U.S. Industrial Outlook. Washington, D.C. p. 2-5.

49. Reference 25. p. 8-3.

50. Telecon. Harris, J. M., U.S. Department of Commerce, with Ando, F. H., JACA. February 28, 1983. Companies in the flat glass industry.

51. Reference 25. pp. 8-3 to 8-4.

52. Reference 25. p. 8-5.

53. Reference 48. p. 2-6.

54. U.S. Department of Commerce. Bureau of the Census. Current Industrial Report: Flat Glass. MQ-32A. 1981. p. 2.

55. U.S. Department of Commerce. Bureau of the Census. Current Industrial Report: Flat Glass. MQ-32A. 1979. p. 3.

56. U.S. Department of Commerce. Bureau of the Census. Current Industrial Report: Flat Glass. MQ-32A. 1978. p. 3.

57. U.S. Department of Commerce. Bureau of the Census. Current Industrial Report: Flat Glass. MQ-32A. 1977. pp. 2, 3.

58. U.S. Department of Commerce. Bureau of the Census. Current Industrial Report: Flat Glass. MQ-32A. 1974. p. 2.

59. U.S. Department of Commerce. Bureau of the Census. Current Industrial Report: Flat Glass. MQ-32A. 1973. p. 2.

60. U.S. Department of Commerce. Bureau of the Census. Current Industrial Report: Flat Glass. MQ-32A. 1971. p. 2.

61. Telecon. Harris, J. M. U.S. Department of Commerce, with Ando, F. H., JACA. February 22, 1983. Price of flat glass.

62. U.S. Department of Commerce. Bureau of the Census. Current Industrial Reports: Glass Containers. M32G. 1981.

63. Reference 25. p. 8-10.

64. Telecon. Roland, G., Glass Packaging Institute, with Ando, F. H., JACA. March 1, 1983. Container Industry.

65. Reference 25. p. 8-17.

66. Reference 48. p. 6-5.

67. Reference 48. p. 6-4.

68. Reference 48. p. 6-6.

69. Telecon. Lofquist, W. S., U.S. Department of Commerce, with Ando, F., H., JACA. February 22, 1982. Price of Container Glass.

70. U.S. Department of Commerce. Bureau of the Census. Current Industrial Report: Glass Containers. M32G. 1981. p. 3.

71. U.S. Department of Commerce. Bureau of the Census. Current Industrial Report: Glass Containers. M32G. 1980. p. 4.

72. U.S. Department of Commerce. Bureau of the Census. Current Industrial Report: Glass Containers. M32G. 1978. p. 4.

73. U.S. Department of Commerce. Bureau of the Census. Current Industrial Report: Glass Containers. M32G. 1979. p. 4.

74. U.S. Department of Commerce. Bureau of the Census. Current Industrial Report: Glass Containers. M32G. 1977. p. 4.

75. Telecon. Hanks, R., U.S. Bureau of the Census, with Miller, L. March 1, 1983. Container shipments and quantity data, 1970 to 1975.

76. Telecon. Cherill, J., Corning Glass, with Ando, F. H., JACA. March 16, 1983. Borasilicate light bulb blanks.

77. Telecon. Cherill, J., Corning Glass, with Ando, F. H., JACA. March 16, 1983. Borasilicate tubing.

78. Annual Report for Corning Glass for the Fiscal Year ending December 31, 1981. p. 29.

79. Annual Report for Corning Glass for the Fiscal Year ending December 31, 1980. p. 30.

80. Annual Report for RCA for the Fiscal Year ending December 31, 1981. p. 38.

81. Annual Report for RCA for the Fiscal Year ending December 31, 1980. p. 36.

82. Annual Report for Anchor Hocking for the Fiscal Year ending December 31, 1981. p. 25.

83. Annual Report for Anchor Hocking for the Fiscal Year ending December 31, 1980. p. 32.

84. Annual Report for GTE for the Fiscal Year ending December 31, 1981. p. 25.

85. Annual Report for Owens-Illinois for the Fiscal Year ending December 31, 1981. p. 38.

86. Annual Report for Owens-Illinois for the Fiscal Year ending December 31, 1980. p. 36.

87. Annual Report for General Electric for the Fiscal Year ending December 31, 1981. p. 49.

88. Annual Report for PPG for the Fiscal Year ending December 31, 1981. pp. 17-18.

89. Annual Report for PPG for the Fiscal Year ending December 31, 1980. p. 20.

90. Annual Report for Libbey-Owens-Ford for the fiscal year ending December 31, 1981. p. 21.

91. Reference 74. p. 42.

92. Reference 81. p. 40.

93. Reference 78. p. 27.

94. Reference 79. p. 29.

95. Reference 76. p. 41.

96. Reference 77. p. 39.

97. Reference 80. p. 26.

98. Telecon. Bronstein, H., U.S. Small Business Administration (SBA) with Ando, F. H., JACA. March 21, 1983. Size standards for SIC 3229.

99. Electronic Yellow Pages - Manufactures Directory. Market Data Retrieval, Inc., Westport, Connecticut. April 29, 1983.

APPENDIX A

EVOLUTION OF THE BACKGROUND INFORMATION DOCUMENT

DATE	NATURE OF ACTION
1/12/83	Effective date of court order to develop inorganic arsenic NESHAP regulations.
1/26/83	Selection of source category.
1/28/83	Begin literature review.
2/7/83	Working group meeting.
2/7/83	Begin telephone contacts with flat glass industry.
2/7/83	Begin telephone contacts to update arsenic emissions data from glass furnaces.
3/2/83	Visits to glass plants with add-on particulate control devices.
3/31/83	NAPCTAC package mailout to industry consisting of Preliminary Study of Sources of Arsenic Emissions.

APPENDIX B

INDEX TO ENVIRONMENTAL CONSIDERATIONS

This appendix consists of a reference system which is cross-indexed with the October 21, 1974 _Federal Register_ (39 FR 37419) containing the Agency guidelines for the preparation of Environmental Impact Statements. This index can be used to identify sections of the document which contain data and information germane to any portion of the _Federal Register_ guidelines.

APPENDIX B

INDEX TO ENVIRONMENTAL IMPACT CONSIDERATIONS

Agency Guidelines for Preparing Regulatory Action Environmental Impact Statements (39 FR 37419)	Location Within the Background Information Document (BID)
1. Background and Description	
Summary of the Regulatory Alternatives	The regulatory alternatives are summarized in Chapter 1, Section 1.2.
Industry Affected	A description of the industry to be affected is given in Chapter 7, Section 7.1.
Sources Affected	Descriptions of the various sources to be affected are given in Chapter 2, Section 2.2.
Availability of Control Technology	Information on the availability of control technology is given in Chapter 3.
2. Regulatory Alternatives	
Regulatory Alternative 1 - No Action (Baseline)	
Environmental Impacts	Environmental effects of Regulatory Alternative I are considered in Chapter 5.
Costs	No capital costs are associated with Regulatory Alternative 1, and thus a cost analysis is not included.

INDEX TO ENVIRONMENTAL IMPACT CONSIDERATIONS (Continued)

Agency Guidelines for Preparing Regulatory Action Environmental Impact Statements (39 FR 37419)	Location Within the Background Information Document (BID)
Regulatory Alternative II -	
Environmental Impacts	Environmental effects associated with Regulatory Alternative II emission control systems are considered in Chapter 5.
Costs	The cost impact of Regulatory Alternative II emission control systems is considered in Chapter 6.
Regulatory Alternative III -	
Environmental Impacts	The implementation of this alternative would require a ban on arsenic emissions from glass furnaces. Arsenic emissions would be zero.
Costs	This alternative could not be implemented without closing glass furnaces which presently use arsenic. This alternative would not require capital costs, and hence costs were not evaluated.

APPENDIX C

EMISSION SOURCE TEST DATA

The purpose of this appendix is to present arsenic emissions test data used in the development of this background information document. Arsenic emission test results were available for two glass furnaces and are presented in this appendix. Both tests were conducted by the U. S. Environmental Protection Agency. One test was performed on a furnace at Corning Glass Works' State College, Pennsylvania plant. This furnace is equipped with an electrostatic precipitator. The other test was performed on a furnace at Corning Glass Works' Central Fall, Rhode Island plant. This furnace is equipped with a fabric filter. The results of the two tests are described below.

C.1 CORNING GLASS WORKS, STATE COLLEGE, PENNSYLVANIA

The Corning Glass Works plant in State College, Pennsylvania, was tested by the Emission Measurement Branch, Field Testing Section of the Environmental Protection Agency (EPA). The purpose of testing the Corning Glass plant was to gather data that could possibly be used to support the setting of standards of performance for the glass industry. The furnace tested attains a temperature of approximately 1200°C. The greatest level of pollution from the plant comes from the melt tank emissions which are directed through the plant's control equipment (an ESP) and eventually out the stack.

Corning Glass Works feeds two types of batch material into the melt tanks. One type is the raw material for glass made up of approximately 50 percent sand and smaller concentrations of arsenic, lead, silicon, fluorine, aluminum oxide, sodium nitrate, boric acid, and anhydrous borax. The lesser concentrations vary depending on the batch and the type of glass being manufactured. The other component of the melt tank feed is previously rejected glass from the earlier melts. The rejected glass is called cullet glass. The raw material and the cullet were mixed in a 1:1 ratio (during the emissions tests) and fed into the melt tank for approximately 48 hours. The conditioned glass is then removed from the melt tank and continues on to the molding process.

The gases from this melting process flow from the melt tank through a spray tower and on to the electrostatic precipitator (ESP). From the ESP the gases are directed to the outlet stack. The water spray in the spray tower is used only when an equipment design temperature is exceeded.

The control device was sampled, generally, in accordance with the draft Method 108. Since Method 108 is designed for use at non-ferrous smelters where high levels of SO_2 are expected, impingers containing solutions of H_2O_2 are utilized. However, at the Corning Glass Works only very small amounts of SO_2 were present, therefore, the impinger solutions were changed to contain only H_2O to trap the gaseous arsenic and moisture in the gas stream. Cleanup of the impinger portion of the train was done using a solution of NaOH in accordance with Method 108. All other requirements of sampling using Method 108 were used along with any Federal Register methods needed to perform Method 108.

During the arsenic emission tests an integrated gas sample was taken at a single point according to Method 3 and analyzed by Orsat to determine the stack gas molecular weight and excess air. Also run simultaneously with the sampling runs for arsenic was Method 9, an opacity determination by a single observer, started 30 minutes before and ended 30 minutes after the runs.

Grab samples of ESP dust, feed material, slag and product were collected during each run. These samples were analyzed for arsenic content. All arsenic analysis was performed by Atomic Absorption Spectrophotometry (AA). Analysis was performed directly on the liquid samples and on the solid samples after being digested.

Samples showing high arsenic levels were quantitated using Flame Atomic Absorption, while the low-level samples were quantitated by Atomic Absorption using the hydride generation technique.

A total of six arsenic emission tests were conducted at the ESP outlet stack of the furnace. Table C-1 summarizes the arsenic data under

TABLE C-1. SUMMARY OF UNCONTROLLED ARSENIC EMISSIONS (ESP)

Run Number	2	4	6	
Date	9/19/78	9/20/78	9/21/78	
Volume of gas sampled - DNCM[a]	1.49	1.57	1.54	
Percent moisture by volume	12.13	11.57	13.51	
Average stack temperature - °C	207	210	209	
Stack volumetric flow rate - DNCMPM[b]	865	885	852	
Stack volumetric flow rate - ACMPM	1674	1711	1677	
Percent isokinetic	97.0	100.1	101.7	
Duration of run - minutes	120	120	120	
Arsenic loading				
Front half - mg	21.10	22.80	26.20	
- g/DNCM	0.0141	0.0145	0.0170	
- kg/hr	0.732	0.767	0.868	
Back half - mg	0.000	0.10	0.000	
- g/DNCM	0.0000	0.0001	0.0000	
- kg/hr	0.000	0.004	0.000	
Total - mg	21.10	22.90	26.20	
- g/DNCM	0.0141	0.0146	0.0170	
- kg/hr	0.732	0.771	0.868	

[a] Dry normal cubic meters at 20°C, 760 mm Hg

[b] Dry normal cubic meters per minute

uncontrolled conditions, when the electrical current to the ESP was off. Table C-2 summarizes the arsenic data during controlled conditions, when the electrical current to the ESP was on. All arsenic data is reported as elemental arsenic.

C.2 CORNING GLASS WORKS, CENTRAL FALLS, RHODE ISLAND

The corning Glass Works plant in Central Falls, Rhode Island, was tested by the Emission Measurement Branch, Field Testing Section of the Environmental Protection Agency (EPA). The purpose of testing the Corning Glass plant was to gather data that could possibly be used to support the setting of standards of performance for the glass industry.

The furnace attains a temperature of approximately 1400°C. The emissions from the furnace are directed through the contral equipment (a fabric filter) and eventually out the stack. Corning Glass Works mixes feed batch and feed cullet with hot cullet return in the melt tank. Also mixed with these raw materials is a solution of arsenic acid. From the melting tank, product is sent to molding and cutting machines. Excess glass from molding forms and any glass produced during stoppages of the molding production line is recycled as hot cullet return.

The gas stream leaves the melting tank and enters the regenerators where slag is removed. Regenerator exhaust enters the baghouse where particulate is collected. Gas from the baghouse is vented to the atmosphere.

The baghouse was sampled generally in accordance with the draft Method 108. Method 108 is designed for use at nonferrous smelters where high levels of SO_2 are expected. At this furnace, only very small amount of SO_2 were present, therefore, impinger solutions were changed from H_2O_2 to H_2O to trap the gaseous arsenic and moisture in the gas stream. Cleanup of the impinger portion of the train was done using a solution of NaOH in accordance with Method 108. All other requirements of sampling using Method 108 were used along with any Federal Register methods needed to perform Method 108.

TABLE C-2. SUMMARY OF CONTROLLED ARSENIC EMISSIONS (ESP)

Run Number	1	3	5	
Date	9/19/78	9/20/78	9/21/78	
Volume of gas sampled - DNCM^a	1.62	1.60	1.59	
Percent moisture by volume	13.96	12.22	12.41	
Average stack temperature - °C	210	210	208	
Stack volumetric flow rate - DNCMPM^b	840	891	877	
Stack volumetric flow rate - ACMPM	1669	1736	1701	
Percent isokinetic	108.4	101.3	102.2	
Duration of run - minutes	120	120	120	
Arsenic loading				
^{c}Front half - mg	0.049	0.042	0.15	
- g/DNCM^c	0.0000	0.0000	0.0001	
- kg/hr	0.002	0.001	0.005	
Back half - mg	0.003	0.001	0.000	
- g/DNCM^c	0.0000	0.0000	0.0000	
- kg/hr	0.0000	0.000	0.0000	
Total - mg	0.05	0.04	0.15	
- g/DNCM^c	0.0000	0.0000	0.0001	
- kg/hr	0.002	0.001	0.005	

[a] Dry normal cubic meters at 20°C, 760 mm Hg

[b] Dry normal cubic meters per minute

[c] Grams per dry normal cubic meter

During the arsenic emission tests, an integrated gas sample was taken at a single point according to Method 3 and analyzed by Orsat to determine the stack gas molecular weight and excess air. Also run simultaneously with the sampling runs for arsenic was Method 9, an opacity determination by a single observer, started 30 minutes before and ended 30 minutes after the runs.

Grab samples of baghouse dust, feed material, slag and product were collected during each run. All arsenic analysis was performed by Atomic Absorption Spectrophotometry (AA). Analysis was performed directly on the liquid samples and on the solid samples after being digested. Samples showing high arsenic levels were quantitated using Flame Atomic Absorption, while the low-level samples were quantitated by Atomic Absorption using the hydride generation technique.

A total of eight arsenic emission tests were performed at the fabric filter inlet and outlet stack. Table C-3 summarizes the arsenic data at the inlet. Table C-4 summarizes the arsenic data at the outlet. All arsenic data are reported as elemental arsenic.

TABLE C-3. SUMMARY OF INLET ARSENIC EMISSIONS (FABRIC FILTER)

Run Number	I-1	I-2	I-3	I-4
Date	10/10/78	10/11/78	10/11/78	10/12/78
Volume of gas sampled - DNCM[a]	2.55	2.58	2.68	2.47
Percent moisture by volume	3.24	3.50	3.71	3.53
Average stack temperature - °C	238	235	240	235
Stack volumetric flow rate - DNCMPM[b]	189	180	189	173
Stack volumetric flow rate - ACMPM	346	327	350	324
Percent isokinetic	97.5	103.9	102.5	103.0
Duration of run - minutes	128	128	128	128
Arsenic loading				
Front half - mg	68.30	59.80	62.50	62.40
- g/DNCM	0.0267	0.0231	0.0233	0.0253
- kg/hr	0.303	0.250	0.264	0.263
Back half - mg	4.70	4.70	5.90	7.60
- g/DNCM	0.0019	0.0018	0.0022	0.0030
- kg/hr	0.021	0.019	0.025	0.032
Total - mg	73.00	64.50	68.40	70.00
- g/DNCM	0.0286	0.0249	0.0255	0.0283
- kg/hr	0.324	0.269	0.289	0.295

[a] Dry normal cubic meters at 20°C, 760 mm Hg

[b] Dry normal cubic meters per minute

TABLE C-4. SUMMARY OF OUTLET ARSENIC EMISSIONS (FABRIC FILTER)

Run Number	0-1	0-2	0-3	0-4
Date	10/10/78	10/11/78	10/11/78	10/12/78
Volume of gas sampled - DNCM[a]	1.91	1.98	1.91	1.93
Percent moisture by volume	3.63	3.44	3.70	4.43
Average stack temperature - °C	145	138	135	137
Stack volumetric flow rate - DNCMPM[b]	222	232	222	215
Stack volumetric flow rate - ACMPM	326	333	317	310
Percent isokinetic	97.1	95.8	96.6	101.0
Duration of run - minutes	120	120	120	120
Arsenic loading				
Front half - mg	0.26	0.09	0.05	0.07
- g/DNCM	0.0001	0.0000	0.0000	0.0000
- kg/hr	0.002	0.001	0.0000	0.0000
Back half - mg	2.41	2.51	3.13	4.15
- g/DNCM	0.0013	0.0013	0.0017	0.0022
- kg/hr	0.017	0.017	0.022	0.028
Total - mg	2.67	2.60	3.18	4.22
- g/DNCM	0.0014	0.0013	0.0017	0.0022
- kg/hr	0.019	0.018	0.022	0.028

[a] Dry normal cubic meters at 20°C, 760 mm Hg

[b] Dry normal cubic meters per minute

APPENDIX D

D-1 EMISSION MEASUREMENT METHODS

At the beginning of the testing program, a literature search was conducted to identify available sampling and analytical techniques for determining arsenic emissions. The search revealed that most arsenic emissions are in the form of arsenic trioxide and arsenic pentoxide. According to the literature, the most commonly used arsenic sampling method has been filtration; however, a number of reports have indicated that filtration alone is not adequate, even at ambient temperatures, because arsenic trioxide is a potentially volatile material. Since it was decided to determine the amount of arsenic collected as a particulate, the Method 5 train, with back-up impinger collectors, was chosen as the starting point for the arsenic sampling system. Based on the available information, a dilute sodium hydroxide solution was chosen as a collecting solution for the impingers. This, however, presented a problem since many of the gas streams to be sampled had very high concentrations of sulfur dioxide (SO_2), some as high as 3.5 percent. Therefore, a series of impingers containing hydrogen peroxide was placed between the filter and the first impinger containing sodium hydroxide to remove the SO_2. This was the configuration for the "working train" used during the first four field tests.

Analytical methods for arsenic were better defined in the literature. The most commonly-used procedure is a wet chemical method based on arsine generation, but certain metals including copper are interfering agents with this method. Instrumental techniques include atomic absorption, neutron activation, and x-ray fluorescence. Atomic absorption spectrophotometry (AAS) was chosen as the most promising technique because of its ready availability, familiarity, and low cost; however, arsenic absorbs weakly and only in the extreme ultra-violet area of the spectrum (193.7 nm). At that wavelength, molecular absorption by flame gases and solution species can interfere with arsenic detection. Despite this, conventional AAS can still be used, provided that: (1) the fuel and combustion gas are carefully chosen and nonatomic background correction is used; and (2) arsenic concentrations are relatively high. However, for lower arsenic concentrations, the interference effects necessitate the use of special, more sensitive technique, such as the hydride generator or the carbon rod (flameless) system. Before testing began, both conventional and special AAS methods were compared and evaluated, in terms of their accuracy, precision, and sensitivity.

During the first two field tests, samples were collected with the working train and analyzed either by conventional or carbon rod AAS depending on the arsenic concentration. The analytical results showed that 95 to 100 percent of the arsenic was collected ahead of the NaOH impingers. In the course of analyzing these samples, the following detailed sample preparation procedure was developed. Solid samples were digested with 0.1 N sodium hydroxide, extracted with concentrated nitric acid, evaporated to dryness, and then redissolved in dilute nitric acid. Liquid samples were treated similarly except that there was no need for the sodium hydroxide digestion step. Advantages of the sample preparation procedure include: (1) reduction of the level of the collected sulfuric acid in the liquid sample fraction; (2) dissolution of the arsenic in the solid samples; and (3) production of a similar solution matrix for all the different sample fractions.

After the second test, questions were raised about the sampling and analytical procedures. First of all, laboratory studies of vaporized arsenic trioxide showed no difference in the arsenic collection efficiency of 0.1 N sodium hydroxide and pure water. These results indicated that the arsenic collection mechanism is condensation and that any condenser would be an effective collector. Consequently, the conventional Method 5 train (with H_2O impingers) was suggested as an alternate to the working train and simultaneous testing of the two trains was planned for the next facility.

Second, an evaluation of the different AAS techniques for low-concentration uncovered some precision and accuracy problems with the carbon rod method when large quantities of dissolved solids (particularly sulfates) are present. The hydride generator technique, it was found, gives much more precise and accurate results in the presence of dissolved solids. In view of this, it was decided that all future low-concentration arsenic samples (i.e., too low for conventional AA analysis) would be analyzed by the hydride generator method.

Third, concern was expressed that arsenic was being lost in the evaporation step of sample preparation. To investigate this, recovery studies were performed on standard samples. These studies showed that there is no significant loss of arsenic during the evaporation step.

Fourth, additional studies showed that while arsenic trioxide is soluble in alkaline, acid, and neutral solutions, its rate of dissolution is slow except in alkaline solutions. Therefore, the clean-up procedure for future test was modified, to require that the train be rinsed with 0.1 N sodium hydroxide to insure removal of condensed arsenic.

Fifth, a comparison of arsenic extraction techniques indicated that higher arsenic yields (by up to 200 percent) can be obtained from smelter particulate when a method capable of dissolving the entire sample is used instead of the less rigorous acid extraction procedure. As a result, it was decided that in future tests, filters would be analyzed by both methods, until more conclusive filter extraction data were obtained.

During the third and fourth field tests, the working train was used for sampling, but additional runs were taken during the fifth test using paired trains of the working and alternate procedures. Analysis of the samples from the paired tests showed no significant difference in collection efficiency. Therefore, the final recommendation was to use the alternate train, since it is easier to operate and analyze. During the fifth and final field test, the alternate train was used.

Filters from the third, fourth, and fifth field tests were extracted, using both the total dissolution and acid extraction procedure. The results showed that filters extracted by the less rigorous method could in some cases yield 25 percent less arsenic than if totally dissolved. Based upon these results, the final recommendation was to extract the filters first by the simple acid extraction; the, if any undissolved sample remained, to extract the undissolved solids by the total dissolution method.

D-2 CONTINUOUS MONITORING

There is currently no available method for continuously monitoring arsenic emissions. For purposes of demonstrating proper operation and maintenance of control devices, continuous monitors are available for measuring opacity from baghouses or electrostatic precipitators, and measuring pressure drop across scrubbers. However, these measurements are not necessarily indicators of the magnitude of arsenic emissions and should not be used for compliance determinations. In addition, opacity may not be applicable as an indicator of proper operation and maintenance where baghouses and precipitators are used to control captured fugitive emissions because of the uncontrolled particulate is very low in concentration.

The recommended monitoring program for continually assessing arsenic emissions is a periodic application of the performance test Method 108 as recommended in Part D-3 below. This is the only method evaluated at this time for demonstration of compliance with arsenic emissions.

D-3 PERFORMANCE TEST METHODS

The recommended performance test method for arsenic is Method 108. Based on the development work already discussed, the method uses the Method 5 train for sampling, 0.1 N sodium hydroxide for cleanup, and either conventional or hydride generator AAS for sample analysis. In order to perform Method 108, Methods 1 through 4 must also be used. Subpart A or 40 CFR 60 requires that facilities subject to standards of performance for new stationary sources be constructed so as to provide sampling ports adequate for the applicable test methods, and platforms, access, and utilities necessary to perform testing at those ports.

Sampling costs for performing a test consisting of three Method 108 runs is estimated to range from $10,000 to $14,000. If in-plant personnel are used to conduct tests, the costs will be somewhat less.

D-4 BIBLIOGRAPHY

1. Hefflefinger, R. E. and D. L. Chase (Battelle). Analysis of Copper Smelter Samples for Arsenic Content. Prepared for U. S. Environmental Protection Agency. Research Triangle Park, N. C. April 1977. 14 p.

2. Haile, D. M. (Monsanto Research Corporation). Final Report on the Development of Analytical Procedures for the Determination of Arsenic from Primary Copper Smelters. Prepared for U. S. Environmental Protection Agency. Research Triangle Park, N. C. February 1978. 27 p.

3. Harris, D. L. (Monsanto Research Corporation). Particulate and Arsenic Emission Measurements from a Copper Smelter. Prepared for the U. S. Environmental Protection Agency. Research Triangle Park, N. C. 77-CUS-5. April 1977. 48 p.

4. Harris, D. L. (Monsanto Research Corporation). Particulate and Arsenic Emission Measurements from a Copper Smelter. Prepared for the U. S. Environmental Protection Agency. Research Triangle Park, N. C. 77-CUS-6. June 1977. 276 p.

5. TRW, Inc. Emission Testing of Asarco Copper Smelter. Prepared for the U. S. Environmental Protection Agency. Research Triangle Park, N. C. 77-CUS-7. April 1978. 150 p.

APPENDIX E

QUANTITATIVE EXPRESSIONS OF PUBLIC CANCER RISKS FROM EMISSIONS OF INORGANIC ARSENIC FROM GLASS MANUFACTURING PLANTS

QUANTITATIVE EXPRESSIONS OF PUBLIC CANCER RISKS FROM THE EMISSIONS OF INORGANIC ARSENIC FROM GLASS MANUFACTURING PLANTS

E.1 INTRODUCTION

E.1.1 Overview

The quantitative expressions of public cancer risks presented in this appendix are based on (1) a dose-response model that numerically relates the degree of exposure to airborne inorganic arsenic to the risk of getting lung cancer, and (2) numerical expressions of public exposure to ambient air concentrations of inorganic arsenic estimated to be caused by emissions from stationary sources. Each of these factors is discussed briefly below and details are provided in the following sections of this appendix.

E.1.2 The Relationship of Exposure to Cancer Risk

The relationship of exposure to the risk of getting lung cancer is derived from epidemiological studies in occupational settings rather than from studies of excess cancer incidence among the public. The epidemiological methods that have successfully revealed associations between occupational exposure and cancer for substances such as asbestos, benzene, vinyl chloride, and ionizing radiation, as well as for inorganic arsenic, are not readily applied to the public sector, with its increased number of confounding variables, much more diverse and mobile exposed population, lack of consolidated medical records, and almost total absence of historical exposure data. Given such uncertainties, EPA considers it improbable that any association, short of very large increases in cancer, can be verified in the general population with any reasonable certainty by an epidemiological study. Furthermore, as noted by the National Academy of Sciences (NAS)[1], "...when there is exposure to a material, we are not starting at an origin of zero cancers. Nor are we starting at an origin of zero carcinogenic agents in our environment. Thus, it is likely that any carcinogenic agent added to the environment will act by a particular mechanism on a particular cell population that is already being acted on by the same mechanism to induce cancers." In discussing experimental dose-response curves, the NAS observed that most information on carcinogenesis is derived from studies of ionizing radiation with experimental animals and with humans which indicate a linear no-threshold dose-response relationship at low doses. They added that although some evidence exists for thresholds in some animal tissues, by and large, thresholds have not been established for most tissues. NAS concluded that establishing such low-dose thresholds "...would require massive, expensive, and impractical experiments ..." and recognized that the U.S. population "...is a large, diverse, and genetically heterogeneous group exposed to a large variety of toxic agents." This fact, coupled with the known genetic variability to carcinogenesis and the predisposition of some individuals to some form of cancer, makes it extremely difficult, if not impossible, to identify a threshold.

For these reasons, EPA has taken the position, shared by other Federal regulatory agencies, that in the absence of sound scientific evidence to the contrary, carcinogens should be considered to pose some cancer risk at any exposure level. This no-threshold presumption is based on the view that as little as one molecule of a carcinogenic substance may be sufficient to transform a normal cell into a cancer cell. Evidence is available from both the human and animal health literature that cancers may arise from a single transformed cell. Mutation research with ionizing radiation in cell cultures indicates that such a transformation can occur as the result of interaction with as little as a single cluster of ion pairs. In reviewing the available data regarding carcinogenicity, EPA found no compelling scientific reason to abandon the no-threshold presumption for inorganic arsenic.

In developing the exposure-risk relationship for inorganic arsenic, EPA has assumed that a linear no-threshold relationship exists at and below the levels of exposure reported in the epidemiological studies of occupational exposure. This means that any exposure to inorganic arsenic is assumed to pose some risk of lung cancer and that the linear relationship between cancer risks and levels of public exposure is the same as that between cancer risks and levels of occupational exposure. EPA believes that this assumption is reasonable for public health protection in light of presently available information. However, it should be recognized that the case for the linear no-threshold dose-response relationship model for inorganic arsenic is not quite as strong as that for carcinogens which interact directly or in metabolic form with DNA. Nevertheless, there is no adequate basis for dismissing the linear no-threshold model for inorganic arsenic. The exposure-risk relationship used by EPA represents only a plausible upper-limit risk estimate in the sense that the risk is probably not higher than the calculated level and could be much lower.

The numerical constant that defines the exposure-risk relationship used by EPA in its analysis of carcinogens is called the unit risk estimate. The unit risk estimate for an air pollutant is defined as the lifetime cancer risk occurring in a hypothetical population in which all individuals are exposed continuously from birth throughout their lifetimes (about 70 years) to a concentration of one $\mu g/m^3$ of the agent in the air which they breathe. Unit risk estimates are used for two purposes: (1) to compare the carcinogenic potency of several agents with each other, and (2) to give a crude indication of the public health risk which might be associated with estimated air exposure to these agents. The comparative potency of different agents is more reliable when the comparison is based on studies of like populations and on the same route of exposure, preferably inhalation.

The unit risk estimate for inorganic arsenic that is used in this appendix was prepared by combining the three different exposure-risk numerical constants developed from three occupational studies.[2] The unit risk estimate is expressed as a range that reflects the statistical uncertainty associated with combining the three exposure-risk relationships. The methodology used to develop the unit risk estimate is described in E.2 below. EPA is updating its health effects assessment document for inorganic arsenic. A preliminary estimate by EPA's health scientists is that the unit risk estimate may change.

E.1.3 Public Exposure

The unit risk estimate is only one of the factors needed to produce quantitative expressions of public health risks. Another factor needed is a numerical expression of public exposure, i.e., of the numbers of people exposed to the various concentrations of inorganic arsenic. The difficulty of defining public exposure was noted by the National Task Force on Environmental Cancer and Health and Lung Disease in their 5th Annual Report to Congress, in 1982.[3] They reported that "...a large proportion of the American population works some distance away from their homes and experience different types of pollution in their homes, on the way to and from work, and in the workplace. Also, the American population is quite mobile, and many people move every few years." They also noted the necessity and difficulty of dealing with long-term exposures because of "...the long latent period required for the development and expression of neoplasia [cancer]..."

EPA's numerical expression of public exposure is based on two estimates. The first is an estimate of the magnitude and location of long-term average ambient air concentrations of inorganic arsenic in the vicinity of emitting sources based on dispersion modeling using long-term estimates of source emissions and meteorological conditions. The second is an estimate of the number and distribution of people living in the vicinity of emitting sources based on Bureau of Census data which "locates" people by population centroids in census tract areas. The people and concentrations are combined to produce numerical expressions of public exposure by an approximating technique contained in a computerized model. The methodology is described in E.3 below.

E.1.4 Public Cancer Risks

By combining numerical expressions of public exposure with the unit risk estimate, two types of numerical expressions of public cancer risks are produced. The first, called individual risk, relates to the person or persons estimated to live in the area of highest concentration as estimated by the dispersion model. Individual risk is expressed as "maximum lifetime risk." As used here, the work "maximum" does not mean the greatest possible risk of cancer to the public. It is based only on the maximum exposure estimated by the procedure used. The second, called aggregate risk, is a summation of all the risks to people estimated to be living within the vicinity (usually within 20 kilometers) of a source and is customarily summed for all the sources in a particular category. The aggregate risk is expressed as incidences of cancer among all of the exposed population after 70 years of exposure; for statistical convenience, it is often divided by 70 and expressed as cancer incidences per year. These calculations are described in more detail in E.4 below.

There are also risks of nonfatal cancer and of serious genetic effects, depending on which organs receive the exposure. No numerical expressions of such risks have been developed; however, EPA considers all of these risks when making regulatory decisions on limiting emissions of inorganic arsenic.

E.2 THE UNIT RISK ESTIMATE FOR INORGANIC ARSENIC[2]

E.2.1 The Linear No-Threshold Model for Estimation of Unit Risk Based on Human Data (General)[4]

Very little information exists that can be utilized to extrapolate from high exposure occupational studies to low environmental levels. However, if a number of simplifying assumptions are made, it is possible to construct a crude dose-response model whose parameters can be estimated using vital statistics, epidemiologic studies, and estimates of worker exposures. In human studies, the response is measured in terms of the relative risk of the exposed cohort of individuals compared to the control group. The mathematical model employed assumes that for low exposures the lifetime probability of death from lung cancer (or any cancer), P, may be represented by the linear equation

$$P = A + B_H x \qquad (1)$$

where A is the lifetime probability of cancer in the absence of the agent, x is the average lifetime exposure to environmental levels in micrograms per cubic meter ($\mu g/m^3$) and B_H is the increased probability of cancer associated with each $\mu g/m^3$ increase of the agent in air.

If we make the assumption that R, the relative risk of lung cancer for exposed workers, compared to the general population, is independent of the length or age of exposure but depends only upon the average lifetime exposure, it follows that

$$R = \frac{P}{P_0} = \frac{A + B_H (x_0 + x_1)}{A + B_H (x_0)} \qquad (2)$$

or

$$RP_0 = A + B_H (x_0 + x_1) \qquad (3)$$

where x_0 = lifetime average exposure to the agent for the general population, x_1 = lifetime average exposure to the agent in the occupational setting, and P_0 = lifetime probability of respiratory cancer applicable with no or negligible arsenic exposure. Substituting $P_0 = A + B_H x_0$ and rearranging gives

$$B_H = P_0 (R - 1)/x_1 \qquad (4)$$

To use this model, estimates of R and x_1 must be obtained from the epidemiologic studies. The value P_0 is derived from the age-cause-specific death rates for combined males found in 1976 U.S. Vital Statistics tables using the life table methodology. For lung cancer the estimate of P_0 is 0.036.[4]

E.2.2 The Unit Risk Estimate for Inorganic Arsenic[2]

As noted in the health effects assessment document[5] for inorganic arsenic, there are numerous occupational studies which relate increased cancer rates to arsenic exposure. Based on these studies, it is concluded in the health assessment document that there is substantial evidence that inorganic arsenic is a human carcinogen. However, many of these studies are inappropriate for use in developing a unit risk estimate for inorganic arsenic because the route of exposure was not by inhalation or because it was impossible to make a reasonable estimate of the population's lifetime average exposure.

Three studies, Lee and Fraumeni (1969), Ott et al. (1974), and Pinto et al. (1977), contained enough pertinent information to make independent quantitative estimates of human cancer risks due to human exposures to atmospheric arsenic. The crudeness of the exposure estimates in those studies is due to such factors as high variability in the chemical measurement of arsenic, a scarcity of monitoring data, and the necessity of working from summarized data tables presented in the literature rather than complete data on all individuals. However, by accepting the data in spite of its recognized limitations, and making a number of simplifying assumptions concerning dose-response relationships and exposure patterns, it was possible to estimate the carcinogenic potency of arsenic. Using a linear model, it was estimated that the increase in the lung cancer rate per increase of 1 $\mu g/m^3$ of atmospheric arsenic was 9.4% (Pinto et al.), 17.0% (Ott et al.), and 3.3% (Lee and Fraumeni). The consistency of these estimates is very good considering the relative crudeness of the data upon which they are based. The geometric mean of the rate estimates from the three studies was calculated to be 8.1%. Using this value as a best estimate and applying equation 4, one calculates the unit risk estimate of 2.95×10^{-3} per $\mu g/m^3$.

If we assume that the linear model and exposure estimates are correct, so that the only source of uncertainty is from combining results from the three different studies, a 95% confidence interval for the above unit risk estimate may be obtained. Upper and lower 95% confidence limits can be obtained by multiplying the unit risk estimate by about 4 and 0.25 respectively. Thus, the 95% statistical confidence limits for the unit risk estimate range from 7.5×10^{-4} to 1.2×10^{-2}.

E.3 QUANTITATIVE EXPRESSIONS OF PUBLIC EXPOSURE TO INORGANIC ARSENIC EMITTED FROM LOW-ARSENIC PRIMARY COPPER SMELTERS

E.3.1 EPA's Human Exposure Model (HEM) (General)

EPA's Human Exposure Model is a general model capable of producing quantitative expressions of public exposure to ambient air concentrations of pollutants emitted from stationary sources. HEM contains (1) an atmospheric dispersion model, with included meteorological data, and (2) a population distribution estimate based on Bureau of Census data. The only input data needed to operate this model are source data, e.g., plant location, height of the emission release point, and temperature of the off-gases. Based on the source data, the model estimates the magnitude and distribution of ambient air concentrations of the pollutant in the vicinity of the source. The model is programmed to estimate these concentrations within a radial distance of 20 kilometers from the source. If other radial distances are preferred, an over-ride feature allows the user to select the distance desired. The selection of 20 kilometers as the programmed distance is based on modeling considerations, not on health effects criteria or EPA policy. The dispersion model contained in HEM is felt to be reasonably accurate within 20 kilometers. If the user wishes to use a dispersion model other than the one contained in HEM to estimate ambient air concentrations in the vicinity of a source, HEM can accept the concentrations if they are put into an appropriate format.

Based on the radial distance specified, HEM combines numerically the distributions of pollutant concentrations and people to produce quantitative expressions of public exposure to the pollutant.

E.3.1.1 Pollutant Concentrations Near a Source

The dispersion model within the HEM is a gaussian diffusion model that uses the same basic dispersion algorithm as EPA's Climatological Dispersion Model.[6] The algorithm has been simplified to improve computational efficiency.[7] The algorithm is evaluated for a representative set of input values as well as actual plant data, and the concentrations input into the exposure algorithm are arrived at by interpolation. Stability array (STAR) summaries are the principal meteorological input to the HEM dispersion model. STAR data are standard climatological frequency-of-occurence summaries formulated for use in EPA models and available for major U.S. meteorological monitoring sites from the National Climatic Center, Asheville, N.C. A STAR summary is a joint frequency-of-occurence of wind speed, atmospheric stability, and wind direction, classified according to Pasquill's categories. The STAR summaries in HEM usually reflect five years of meteorological data for each of 309 sites nationwide. The model produces polar coordinate receptor grid points consisting of 10 downwind distances located along each of 16 radials which represent wind directions. Concentrations are estimated by the dispersion model for each of the 160 receptors located on this grid. The radials are separated by 22.5-degree intervals beginning with 0.0 degrees and proceeding clockwise to 337.5 degrees. The 10 downwind distances for each radial are 0.2, 0.3, 0.5, 0.7, 1.0, 2.0, 5.0, 10.0, 15.0, and 20.0 kilometers. The center of the receptor grid for each plant is assumed to be the plant center.

E.3.1.2 The People Living Near A Source

To estimate the number and distribution of people residing within 20 kilometers of each plant, the model contains a slightly modified version of the "Master Enumeration District List--Extended" (MED-X) data base.

The data base is broken down into enumeration district/block group (ED/BG) values. MED-X contains the population centroid coordinates (latitude and longitude) and the 1970 population of each ED/BG in the United States (50 States plus the District of Columbia). For human exposure estimates, MED-X has been reduced from its complete form (including descriptive and summary data) to produce a computer file of the data necessary for the estimation. A separate file of county-level growth factors, based on 1978 estimates of the 1970 to 1980 growth factor at the county level, has been used to estimate the 1980 population for each ED/BG. HEM identifies the population around each plant by using the geographical coordinates of the plant. The HEM identifies, selects, and stores for later use those ED/BGs with coordinates falling within 20 kilometers of plant center.

E.3.1.3 Exposure[7]

The Human Exposure Model (HEM) uses the estimated ground level concentrations of a pollutant together with population data to calculate public exposure. For each of 160 receptors located around a plant, the concentration of the pollutant and the number of people estimated by the HEM to be exposed to that particular concentration are identified. The HEM multiplies these two numbers to produce exposure estimates and sums these products for each plant.

A two-level scheme has been adopted in order to pair concentrations and populations prior to the computation of exposure. The two level approach is used because the concentrations are defined on a radius-azimuth (polar) grid pattern with non-uniform spacing. At small radii, the grid cells are usually smaller than ED/BG's; at large radii, the grid cells are usually larger than ED/BG's. The area surrounding the source is divided into two regions, and each ED/BG is classified by the region in which its centroid lies.

Population exposure is calculated differently for the ED/BG's located within each region. For ED/BG centroids located between 0.1 km and 2.8 km from the emission source, populations are divided between neighboring concentration grid points. There are 96 (6 x 16) polar grid points within this range. Each grid point has a polar sector defined by two concentric arcs and two wind direction radials. Each of these grid points and respective concentrations are assigned to the nearest ED/BG centroid identified from MED-X. Each ED/BG can be paired with one or many concentration points. The population associated with the ED/BG centroid is then divided among all concentration grid points assigned to it. The land area within each polar sector is considered in the apportionment.

For population centroids between 2.8 km and 20 km from the source, a concentration grid cell, the area approximating a rectangular shape bounded by four receptors, is much larger than the area of a typical ED/BG. Since there is an approximate linear relationship between the logarithm of concentration and the logarithm of distance for receptors more than 2 km from the source, the entire population of the ED/BG is assumed to be exposed to the concentration that is logarithmically interpolated radially and arithmetically interpolated azimuthally from the four receptors bounding the grid cell. Concentration estimates for 80 (5 x 16) grid cell receptors at 2.0, 5.0, 10.0, 15.0, and 20.0 km from the source along each of 16 wind directions are used as reference points for this interpolation.

In summary, two approaches are used to arrive at coincident concentration/population data points. For the 96 concentration points within 2.8 km of the source, the pairing occurs at the polar grid points using an apportionment of ED/BG population by land area. For the remaining portions of the grid, pairing occurs at the ED/BG centroids themselves through the use of log-log and linear interpolation. (For a more detailed discussion of the model used to estimate exposure, see Reference 7.)

E.3.2 Public Exposure to Inorganic Arsenic Emissions from Glass Manufacturing Plants

E.3.2.1 Source Data

Fifteen glass manufacturing plants are included in the analysis. Table E.1 lists the names and addresses of the plants considered, and Table E.2 lists the plant data used as input to the Human Exposure Model (HEM).

E.3.2.2 Exposure Data

Table E.3 lists, on a plant-by-plant basis, the total number of people encompassed by the exposure analysis and the total exposure. Total exposure is the sum of the products of number of people times the ambient air concentration to which they are exposed, as calculated by HEM. Table E.4 sums, for the entire source category (15 plants), the numbers of people exposed to various ambient concentrations, as calculated by HEM.

TABLE E-1

IDENTIFICATION OF GLASS MANUFACTURING PLANTS

Plant Number Code	Plant Name and Address
1	RCA, Circleville, OH
2	GTE, Versailles, KY
3	Owens-Illinois, Columbus, OH
4	a
5	a
6	a
7	a
8	a
9	a
10	a
11	a
12	a
13	a
14	a
15	a

[a] Companies requested confidential treatment of plant identity associated with input data used in developing risk estimates.

Table E-2 Input Data to Exposure Model Glass Manufacturing

Plant	(Furnace)	Latitude (Degrees Minutes Seconds)	Longtitude (Degrees Minutes Seconds)	Emission Rate (Kg/yr)	Emission Point Elevation (Meters)	Emission Point Diameter (Meters)	Emission* Point Cross Sectional Area (m^2)	Emission Point Gas Exit Velocity m/sec	Emission Point Gas Temp. (°K)	Emission Point Type
1	1	393358	0825718	30.5	22.3	1.52	750	14.02	505	Stack
	2			6.9	9.75	0.95	750	9.32	436	Stack
2		380246	0844504	68.6	15.5	0.70	750	29.3	494	Stack
3		395555	0825823	95.3	21.3	1.58	750	12.7	450	Stack
4	1	394232	0823441	3048.	44.2	1.78	750	6.0	783	Stack
	2			3538.	36.0	1.4	750	10.0	725	Stack
	3			725.	38.1	0.99	750	9.8	700	Stack
	4			544.	19.2	0.80	750	18.0	636	Stack
	5			544.	21.9	1.83	750	4.9	669	Stack
5	1	391554	0763748	1270.	39.6	1.07	750	8.56	655	Stack
	2			907.	29.0	1.52	750	3.0	610	Stack
6	1	391718	0802102	454.	15.0	2.4	750	0.30	310	Vent
	2			1814.	15.24	1.37	750	3.05	644	Stack
	3			3084.	36.6	1.52	750	6.15	700	Stack
7		415346	0712320	194.3	18.3	0.91	750	7.6	410	Stack
8		374518	0844948	49.5	41.1	1.8	750	3.0	440	Stack
9		392613	0775910	15240.7	41.1	2.4	750	3.4	666	Stack
0		363500	0792400	38.1	15.2	4.80	750	1.5	311	Vent
1		405006	0774728	22.9	45.7	1.52	750	15.2	477	Stack
2	1	400817	0795346	952.5	9.1	0.76	750	13.1	672	Stack
	2			952.5	7.6	0.76	750	18.3	755	Stack
	3			1714.6	15.2	0.82	750	29.0	644	Stack
	4			571.5	9.1	0.76	750	18.6	544	Stack
	5			76.2	30.5	1.2	750	17.4	461	Stack
3		420835	0770242	228.6	25.9	1.2	750	22.9	477	Stack
4	1	420842	0770322	76.2	27.9	1.1	750	14.0	755	Stack
	2			38.1	27.9	1.2	750	15.2	477	Stack
5		420838	0770235	114.3	29.0	0.45	750	12.2	644	Stack

*Assumed 750 m^2 for all glass manufacturing plants, this is the vertical cross sectional area of the emission point to the mean wind direction for purpose of calculating downwash.

TABLE E-3 TOTAL EXPOSURE AND NUMBER OF PEOPLE EXPOSED (GLASS MANUFACTURING PLANTS)*

Plant	Total Number of People Exposed	Total Exposure (People - $\mu g/m^3$)
1	41,000	2
2	99,000	4
3	866,000	72
4	79,000	850
5	1,530,000	2300
6	82,000	1200
7	708,000	190
8	48,000	3
9	60,000	1200
10	82,000	23
11	88,000	1
12	204,000	1100
13	96,000	13
14	85,000	55
15	97,000	20

* A 20-kilometer radius was used for the analysis of glass manufacturing plants.

TABLE E-4

Public Exposure for Glass Manufacturing Plants as Produced the Human Exposure Model

Concentration Level (μg/m^3)	Population Exposed (Persons)*	Exposure (Persons- μg/m^3)**
0.863	15	14
0.5	62	44
0.25	212	93
0.1	1755	314
0.05	13517	1010
0.025	49475	2210
0.01	140160	3620
0.005	271060	4540
0.0025	502235	5340
0.001	1106248	6290
0.0005	1719070	6730
0.00025	2212152	6910
0.0001	2657137	6980
0.00005	3331006	7030
0.000025	4048413	7050
0.00001	4144677	7050
0.0000005	4166149	7050
0.00000025	4166150	7050
0.000000147	4166152	7050

*Column 2 displays the computed value, rounded to the nearest whole number, of the cumulative number of people exposed to the matching and higher concentration levels found in column 1. For example, 0.5 people would be rounded to 0 and 0.51 people would be rounded to 1.

**Column 3 displays the computed value of the cumulative exposure to the matching and higher concentation levels found in column 1.

E.4 QUANTITATIVE EXPRESSIONS OF PUBLIC CANCER RISKS FROM INORGANIC ARSENIC EMITTED FROM GLASS MANUFACTURING PLANTS

E.4.1 Methodology (General)

E.4.1.1 The Two Basic Types of Risk

Two basic types of risk are dealt with in the analysis. "Aggregate risk" applies to all of the people encompassed by the particular analysis. Aggregate risk can be related to a single source, to all of the sources in a source category, or to all of the source categories analyzed. Aggregate risk is expressed as incidences of cancer among all of the people included in the analysis, after 70 years of exposure. For statistical convenience, it is often divided by 70 and expressed as cancer incidences per year. "Individual risk" applies to the person or persons estimated to live in the area of the highest ambient air concentrations and it applies to the single source associated with this estimate as estimated by the dispersion model. Individual risk is expressed as "maximum lifetime risk" and reflects the probability of getting cancer if one were continuously exposed to the estimated maximum ambient air concentration for 70 years.

E.4.1.2 The Calculation of Aggregate Risk

Aggregate risk is calculated by multiplying the total exposure produced by HEM (for a single source, a category of sources, or all categories of sources) by the unit risk estimate. The product is cancer incidences among the included population after 70 years of exposure. The total exposure, as calculated by HEM, is illustrated by the following equation:

$$\text{Total Exposure} = \sum_{i=1}^{N} (P_i C_i)$$

where

$\sum$ = summation over all grid points where exposure is calculated

P_i = population associated with grid point i,

C_i = long-term average inorganic arsenic concentration at grid point i,

N = number of grid points to 2.8 kilometers and number of ED/BG centroids between 2.8 and 20 kilometers of each source.

To more clearly represent the concept of calculating aggregate risk, a simplified example illustrating the concept follows:

EXAMPLE

This example uses assumptions rather than actual data and uses only three levels of exposure rather than the large number produced by HEM. The assumed unit risk estimate is 3×10^{-3} at 1 $\mu g/m^3$, and the assumed exposures are:

ambient air concentrations	number of people exposed to given concentration
2 $\mu g/m^3$	1,000
1 $\mu g/m^3$	10,000
0.5 $\mu g/m^3$	100,000

The probability of getting cancer if continuously exposed to the assumed concentrations for 70 years is given by:

concentration		unit risk		probability of cancer
2 $\mu g/m^3$	x	$3 \times 10^{-3} (\mu g/m^3)^{-1}$	=	6×10^{-3}
1 $\mu g/m^3$	x	3×10^{-3} "	=	3×10^{-3}
0.5 $\mu g/m^3$	x	3×10^{-3} "	=	1.5×10^{-3}

The 70 year cancer incidence among the people exposed to these concentrations is given by:

probability of cancer at each exposure level		number of people at each exposure level		cancer incidences after 70 years of exposure
6×10^{-3}	x	1,000	=	6
3×10^{-3}	x	10,000	=	30
1.5×10^{-3}	x	100,000	=	150
			TOTAL =	186

The aggregate risk, or total cancer incidence, is 186 and, expressed as cancer incidence per year, is 186 ÷ 70, or 2.7 cancers per year. The total cancer incidence and cancers per year apply to the total of 111,000 people assumed to be exposed to the given concentrations.

E.4.1.3 The Calculation of Individual Risk

Individual risk, expressed as "maximum lifetime risk," is calculated by multiplying the highest concentration to which the public is exposed, as reported by HEM, by the unit risk estimate. The product, a probability of getting cancer, applies to the number of people which HEM reports as being exposed to the highest listed concentration. The concept involved is a simple proportioning from the 1 $\mu g/m^3$ on which the unit risk estimate is based to the highest listed concentration. In other words:

$$\frac{\text{maximum lifetime risk}}{\text{highest concentration to which people are exposed}} = \frac{\text{the unit risk estimate}}{1\ \mu g/m^3}$$

E.4.2 Risks Calculated for Emissions of Inorganic Arsenic from Glass Manufacturing Plants

The explained methodologies for calculating maximum lifetime risk and cancer incidences were applied to each glass manufacturing plants, assuming a baseline level of emissions. A baseline level of emissions means the level of emissions after the application of controls either currently in place or required to be in place to comply with curent state or Federal regulations but before application of controls that would be required by a NESHAP.

Table E-5 summarizes the calculated risks. To understand the relevance of these numbers, one should refer to the analytical uncertainties discussed in section E.5 below.

TABLE E-5 MAXIMUM LIFETIME RISK AND CANCER INCIDENCE FOR GLASS MANUFACTURING PLANTS
(Assuming Baseline Controls)

Plant	Maximum Lifetime Risk	Cancer Incidences Per Year	Cancer Incidence (one case in [x] years)
1	3.7×10^{-7} - 5.9×10^{-6}	1.6×10^{-5} - 2.6×10^{-4}	1 in 60,000 yrs. - 1 in 4,000 yrs.
2	1.3×10^{-6} - 2.1×10^{-5}	4.2×10^{-5} - 6.7×10^{-4}	1 in 20,000 yrs. - 1 in 1000 yrs.
3	5.0×10^{-7} - 8.0×10^{-6}	7.5×10^{-4} - 1.2×10^{-2}	1 in 1000 yrs. - 1 in 100 yrs.
4	6.2×10^{-5} - 1.0×10^{-3}	8.8×10^{-3} - 1.4×10^{-1}	1 in 100 yrs. - 1 in 7 yrs.
5	7.4×10^{-5} - 1.2×10^{-3}	2.4×10^{-2} - 3.9×10^{-1}	1 in 40 yrs. - 1 in 3 yrs.
6	6.4×10^{-4} - 1.0×10^{-2}	1.2×10^{-2} - 2.0×10^{-1}	1 in 80 yrs. - 1 in 5 yrs.
7	9.2×10^{-6} - 1.5×10^{-4}	2.0×10^{-3} - 3.2×10^{-2}	1 in 500 yrs. - 1 in 30 yrs.
8	1.1×10^{-6} - 1.8×10^{-5}	2.9×10^{-5} - 4.7×10^{-4}	1 in 30,000 yrs. - 1 in 2000 yrs.
9	1.6×10^{-4} - 2.6×10^{-3}	1.2×10^{-2} - 2.0×10^{-1}	1 in 80 yrs. - 1 in 5 yrs.
10	1.1×10^{-5} - 1.7×10^{-4}	2.4×10^{-4} - 3.8×10^{-3}	1 in 4,000 yrs. - 1 in 300 yrs.
11	1.2×10^{-7} - 1.9×10^{-6}	7.2×10^{-6} - 1.2×10^{-4}	1 in 100,000 yrs. - 1 in 9000 yrs.
12	4.6×10^{-5} - 7.3×10^{-4}	1.1×10^{-2} - 1.8×10^{-1}	1 in 90 yrs. - 1 in 6 yrs.
13	8.6×10^{-7} - 1.4×10^{-5}	1.3×10^{-4} - 2.1×10^{-3}	1 in 8000 yrs. - 1 in 500 yrs.
14	3.9×10^{-6} - 6.2×10^{-5}	5.7×10^{-4} - 9.1×10^{-3}	1 in 2000 yrs. - 1 in 100 yrs.
15	4.2×10^{-6} - 6.7×10^{-5}	2.1×10^{-4} - $3\ 3 \times 10^{-3}$	1 in 5000 yrs. - 1 in 300 yrs.

TOTALS FOR THIS SOURCE CATGEGORY

Number of Plants	Total Number of People Exposed (within 20 km)	Highest Individual Risk	Cancer Incidences	
			per year	one case in [x] years
15	4,166,000	6.4×10^{-4} - 1.0×10^{-2} (For Plant 6)	0.07 - 1.2	1 in 10 yrs. - 1 in 1 yr.

NOTE: The ranges in these quantifications of public health impacts reflect the uncertainty of combining the three different dose-response relationships relevant to the three occupational studies which EPA used as the basis for the development of unit risk estimate.[2]

E.5 ANALYTICAL UNCERTAINTIES APPLICABLE TO THE CALCULATIONS OF PUBLIC HEALTH RISKS CONTAINED IN THIS APPENDIX

E.5.1 The Unit Risk Estimate

The procedure used to develop the unit risk estimate is described in reference 2. The model used and its application to epidemiological data have been the subjects of substantial comment by health scientists. The uncertainties are too complex to be summarized sensibly in this appendix. Readers who wish to go beyond the information presented in the reference should see the following Federal Register notices: (1) OSHA's "Supplemental Statement of Reasons for the Final Rule", 48 FR 1864 (January 14, 1983); and (2) EPA's "Water Quality Documents Availability" 45 FR 79318 (November 28, 1980).

The unit risk estimate used in this analysis applies only to lung cancer. Other health effects are possible; these include skin cancer, hyperkeratosis, peripheral neuropathy, growth retardation and brain dysfunction among children, and increase in adverse birth outcomes. No numerical expressions of risks relevant to these health effects is included in this analysis.

E.5.2 Public Exposure

E.5.2.1 General

The basic assumptions implicit in the methodology are that all exposure occurs at people's residences, that people stay at the same location for 70 years, that the ambient air concentrations and the emissions which cause these concentrations persist for 70 years, and that the concentrations are the same inside and outside the residences. From this it can be seen that public exposure is based on a hypothetical rather than a realistic premise.

It is not known whether this results in an over-estimation or an under-estimation of public exposure.

E.5.2.2 The Public

The following are relevant to the public as dealt with in this analysis:

1. Studies show that all people are not equally susceptible to cancer. There is no numerical recognition of the "most susceptible" subset of the population exposed.

2. Studies indicate that whether or not exposure to a particular carcinogen results in cancer may be affected by the person's exposure to other substances. The public's exposure to other substances is not numerically considered.

3. Some members of the public included in this analysis are likely to be exposed to inorganic arsenic in the air in the workplace, and workplace air concentrations of a pollutant are customarily much higher than the concentrations found in the ambient, or public air. Workplace exposures are not numerically approximated.

4. Studies show that there is normally a long latent period between exposure and the onset of lung cancer. This has not been numerically recognized.

5. The people dealt with in the analysis are not located by actual residences. As explained previously, they are "located" in the Bureau of Census data for 1970 by population centroids of census districts. Further, the locations of these centroids has not been changed to reflect the 1980 census. The effect is that the actual locations of residences with respect to the estimated ambient air concentrations is not known and that the relative locations used in the exposure model have changed since the 1970 census.

6. Many people dealt with in this analysis are subject to exposure to ambient air concentrations of inorganic arsenic where they travel and shop (as in downtown areas and suburban shopping centers), where they congregate (as in public parks, sports stadiums, and schoolyards), and where they work outside (as mailmen, milkmen, and construction workers). These types of exposures are not numerically dealt with.

E.5.2.3. The Ambient Air Concentrations

The following are relevant to the estimated ambient air concentrations of inorganic arsenic used in this analysis:

1. Flat terrain was assumed in the dispersion model. Concentrations much higher than those estimated would result if emissions impact on elevated terrain or tall buildings near a plant.

2. The estimated concentrations do not account for the additive impact of emissions from plants located close to one another.

3. The increase in concentrations that could result from re-entrainment of arsenic-bearing dust from, e.g., city streets, dirt roads, and vacant lots, is not considered.

4. Meteorological data specific to plant sites are not used in the dispersion model. As explained, HEM uses the meteorological data from the STAR station nearest the plant site. Site-specific meteorological data could result in significantly different estimates, e.g., the estimates of where the higher concentrations occur.

5. With few exceptions, the arsenic emission rates are based on assumptions rather than on emission tests. See the BID for details on each source.

E.6 References

1. National Academy of Sciences, "Arsenic," Committee on Medical and Biological Effects of Environmental Pollutants, Washington, D.C., 1977. Docket Number (OAQPS 79-8) II-A-3.

2. The Carcinogen Assessment Group's Final Risk Assessment on Arsenic. OAQPS Docket Number 79-8-II-A-7. May 2, 1980.

3. U.S. EPA, et.al., "Environmental Cancer and Heart and Lung Disease," Fifth Annual Report to Congress by the Task Force on Environmental Cancer and Health and Lung Disease, August, 1982.

4. U.S. EPA, "Health Assessment Document for Acrylonitrile," Draft Report from the Office of Health and Assessment, EPA-600/8-82-007, November, 1982.

5. U.S. EPA, "An Assessment of the Health Effects of Arsenic," April 1978, Docket Number (OAQPS 79-8) II-A-5.

6. Busse, A.D. and Zimmerman. J.R., "User's Guide for the Climatological Dispersion Model." (Prepared for the U.S. Environmental Protection Agency, Research Triangle Park, North Carolina.) Publication Number EPA-R4-73-024. December 1973.

7. Systems Application, Inc., "Human Exposure to Atmospheric Concentrations of Selected Chemicals." (Prepared for the U.S. Environmental Protection Agency, Research Triangle Park, North Carolina). Volume I, Publication Number EPA-2/250-1, and Volume II, Publication Number EPA-1/250-2.